

Loudoun County Pedestrian and Bicycle Design Toolkit

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Chapter 1: Introduction

This Design Toolkit is provided as a companion document to the Loudoun County Bicycle and Pedestrian Mobility Master Plan (hereafter referred to as the Master Plan). The Master Plan, called for [taken directly from the Plan document] in the Revised Countywide Transportation Plan, provides an overall planning and policy framework for future development of bicycle and pedestrian facilities in the County. This Design Toolkit provides additional design detail that can be used by County staff, roadway designers, developers, bicycle and pedestrian advocates, citizens active in neighborhood improvement projects and others who are involved in the design and construction of the facilities called for in the Master Plan.

Achieving a safe, convenient and attractive bikeway and walkway network will involve construction of new sidewalks, shared use pathways, bike lanes, and many other types of facilities. An efficient and functional non-motorized transportation network requires attention to both the big picture and the smallest details – from land use and development patterns to the way that a street corner is designed. It involves many different county agencies and individuals, including the development community, elected leaders and residents.

1.1 Purpose of the Toolkit

The purpose of this Toolkit is to provide design guidance on a variety of topics that are pertinent to implementation of the Master Plan. The topics addressed in this design toolkit will ultimately be incorporated into the Loudoun County's Facility Standards Manual (FSM).

This toolkit does not address every topic related to bicycle and pedestrian design. Nor does it reiterate all of the basic design guidelines that are available in such documents as the Manual on Uniform Traffic Control Devices or the AASHTO Guide for the Development of Bicycle Facilities. The reader is encouraged to become familiar with the references noted above and other standard highway, road, bikeway and pedestrian guidance documents. Additional guidance can be obtained from the resources listed at the end of this chapter.

1.2 Scope and Applicability

These guidelines attempt to balance pedestrian and bicyclist needs with the design needs and constraints of other roadway users. It is not desired, or appropriate, to accommodate the needs of one user above the safety of all others. Engineering judgment must be used to ensure a balanced transportation system that supports walking and bicyclists, while also accommodating automobiles, transit vehicles, and trucks.

Some aspects of bicycle and pedestrian design demand a degree of flexibility, while other aspects must comply with standards that have been established at the national, state or local level. These guidelines do not supersede requirements and policies established through community plans, the County's Facility Standards Manual, or other Board-adopted policy or regulatory documents; but, rather, they are designed to work in concert with them.



1.3 Implementing Designs from this Manual

Site conditions and circumstances often make applying a specific solution difficult. Throughout the guidelines, care has been taken to provide flexibility so that designers can tailor their approach to unique circumstances. When the specific guideline cannot be met, the designer must find the solution that best meets the principles presented in Chapter 2.

1.4 The Project Development Process

In order to ensure that pedestrian and bicycle facilities provide satisfactory linkages and contribute to system connectivity throughout the County, the following actions should be taken during the development of projects in public rights-of-way:

- Project scoping should include identification of missing sidewalks and curb ramps, unpaved shoulders, and other potential pedestrian and bicycle facility improvements. Scoping will require a basic field observation to identify pedestrian and bicycle needs. It may be necessary to extend project boundaries to provide continuity for bicycle and pedestrian travel. Sidewalks and bikeways should extend to common destinations and logical terminal points, wherever possible.
- Project concept and preliminary traffic plans should include existing and proposed pedestrian and bicycle features, which may include proposed sidewalk connections and conceptual intersection crossing measures.
- Design plans should indicate layout and construction of all pedestrian facilities in accordance with the County's Improvement Standards.
- Construction traffic control plans must include maintenance of an accessible pedestrian and/or bicycle route through the construction site, whenever an existing route is disrupted.

1.5 Important Design References

Several additional roadway design manuals include pertinent information on bicycle and pedestrian design and should therefore be referenced in conjunction with this Toolkit:

- *Virginia Bicycle Facility Resource Guide*, Virginia Department of Transportation (VDOT), CD-ROM, 2002. Includes chapters on planning, design, encouragement, education, enforcement and funding of bicycle facilities.
- *Americans with Disabilities Act Accessibility Guidelines* (1994, as amended). Provides design standards for sidewalks and street corners, requiring that new and altered facilities be accessible to people with disabilities. Recently revisions have been proposed to address pedestrian design in the public right-of-way.



- *Designing Sidewalks and Trails for Access – Part 1: Review of Existing Guidelines (1999) and Part 2: Best Practices Design Guide (2001)*, Federal Highway Administration (FHWA), Publication No. FHWA-EP-01-027 HEPH/8-01(10M)E. Comprehensive guides for ADA sidewalk and trail design.
- *Manual on Uniform Traffic Control Devices*, millennium edition (2000, as amended), Federal Highway Administration. Provides standards for all traffic control devices, including those related to bicycle and pedestrian traffic, including warrants and design of signs for shared use paths, bike lanes markings and signs, and pedestrian signals, signs and markings in school zones, and other topics.
- *Guide for the Development of Bicycle Facilities*, American Association of State Highway and Transportation Officials (AASHTO), 1999. Provides detailed design guidance on a variety of aspects of bicycle facility design including bike lanes and shared use paths.
- *Guide for the Planning, Design, and Operation of Pedestrian Facilities*, AASHTO (2004, estimated publication year). Will provide detailed design guidance on pedestrian facility design.
- *Alternative Treatments for At-Grade Pedestrian Crossings*, Institute of Transportation Engineers (ITE), 2001. An informational report on over 70 at-grade pedestrian crossing treatments.
- *Highway Capacity Manual*, AASHTO, 2000. Provides directives on how to calculate levels of service (crowding measures) on sidewalks and other pedestrian facilities.
- *A Policy on Geometric Design of Highways and Streets (The Green Book)*, Fourth Edition, AASHTO, 2001.
- *Safety Effects of Marked vs. Unmarked Crosswalks at Uncontrolled Locations: Executive Summary and Recommended Guidelines*, FHWA, Publication No. FHWA-RD-01-075, 2002. This study provides guidance on the use of marked crosswalks at various types of uncontrolled intersections.
- *Pedestrian Facilities Users Guide: Providing Safety and Mobility*, Federal Highway Administration, 2001, Publication No. FHWA-RD-01-102. This FHWA research study describes a range of pedestrian facility design treatments that have been used to improve pedestrian safety in the U.S.
- *Design and Safety of Pedestrian Facilities – A Recommended Practice of the Institute of Transportation Engineers*, ITE, 1998. A compendium of best practices in design and operations related to pedestrians.
- *Traffic Calming: State of the Practice*, ITE and FHWA, 1999. A comprehensive summary regarding application, design, and results for all of the most common, and some of the least common, traffic calming treatment used in the United States. Includes chapters on history, legal and liability implications, emergency response impacts, warrants, programmatic approaches, and community design.



- *Traffic Control Devices Handbook*, ITE, 2001. A supplement to the MUTCD developed by ITE. Describes several new pedestrian signal devices.



Chapter 2: Basic Design of Bicycle and Pedestrian Facilities

2.1 Design Principles

The following principles represent a set of ideals that should be incorporated, to some extent, into every bicycling and walking environment. Some of these ideals go beyond the realm of responsibility of the County or VDOT, and will require coordination with the development community, homeowner associations and other property managers and owners in Loudoun County.

- 1. The street environment should be safe for bicyclists and pedestrians.**
Travel lanes, shoulders, sidewalks and street crossings should be free of hazards and should minimize conflicts with vehicular traffic. The need to accommodate vehicular traffic flow should be balanced with the need to provide for other users, including pedestrians and bicyclists. Street design policy should reflect this balance. Enhanced pedestrian facilities should be considered in high pedestrian areas.
- 2. The pedestrian network should be accessible to all.**
Sidewalks, pathways and street crossings should ensure access for all people, regardless of their physical abilities. Accessible design is, therefore, the foundation for all pedestrian design.
- 3. The bicycle and pedestrian network should be easy to use, provide direct connections to destinations, and generally be open and safe when the public expects to conduct routine travel.**
The bicycle and pedestrian network should provide continuous, direct and convenient connections between destinations, including homes, schools, shopping areas, public services, work places, recreational opportunities and transit. Most roadways, streets, sidewalks, intersections and pathways should be lighted, signed and maintained so that travelers can choose bicycling and walking all year around, in early morning, daylight and evening hours and find a direct and safe route to their destination without delay.
- 4. Street and pathway environments should feel comfortable and inviting to bicyclists and pedestrians.**
Good design should enhance the comfort and appeal of the pedestrian and bicycling environment. Pedestrians should be adequately buffered from adjacent traffic with street trees and other measures. An ideal pedestrian environment might offer resting places and visual elements, such as special paving or street furnishings that provide a sense of place. Bicyclists will find convenient and secure bicycle parking at their destination.
- 5. Bicycle and pedestrian improvements should be economical.**
Bikeways and walkways should be designed to achieve the maximum benefit for their cost, including initial cost and maintenance cost as well as reduced reliance on more expensive modes of transportation.



2.2 Sidewalk and Buffer Design

Sidewalk Definition: “The portion of a street or highway right-of-way designed for preferential or exclusive use by pedestrians.”¹

Buffer Definition: "The portion of a street or highway right-of-way that is located between the curb or shoulder and the sidewalk or sidepath."

Design Guidance:

- Typically, sidewalks should be provided on both sides of the street (see Policy for the Provision of Walkways and Sidewalks, in the Master Plan). Sidewalks in villages, towns and rural areas, and on residential streets in suburban areas, should be a minimum of 5 feet wide. In commercial areas and along residential collectors, a minimum of 6 feet is required, or greater depending on the expected level of pedestrian activity. Generally, sidewalks should be constructed of concrete unless shared use pathways are provided to accommodate pedestrian travel.
- Three to six-foot wide vegetated buffers are recommended for residential streets (minimum: 2 feet). Buffers of 6 feet are recommended for collector roads in a residential or commercial setting (minimum: 4 feet). Buffers of 8 feet are recommended for avenues, boulevards, parkways and other large collector and arterial roads (minimum: 6 feet). Typically, vegetated buffers should also include street trees; tree spacing will vary depending on buffer width and the nature of adjacent land uses. Generally, buffers of 4 feet or greater (depending on the species) are needed to fully support street trees.
- Meandering sidewalks (sidewalks that weave back and forth within the right-of-way) are discouraged. While they seem visually interesting, they are annoying to pedestrians who desire a direct and efficient route. They cause navigational difficulties for people with vision impairments.

There are circumstances, however, when it is desirable to curve a sidewalk: 1) to go around an unmovable barrier, 2) to take advantage of an opportunity increase the separation between the road and the sidewalk (i.e. a wider buffer), or 3) to bring a sidewalk to the proper alignment with a curb ramp and crosswalk at an intersection. This type of occasional shift is acceptable and can be done using gentle curve radii so that pedestrians will still perceive the walking route to be direct and efficient.

2.3 Basic Bike Lane Design

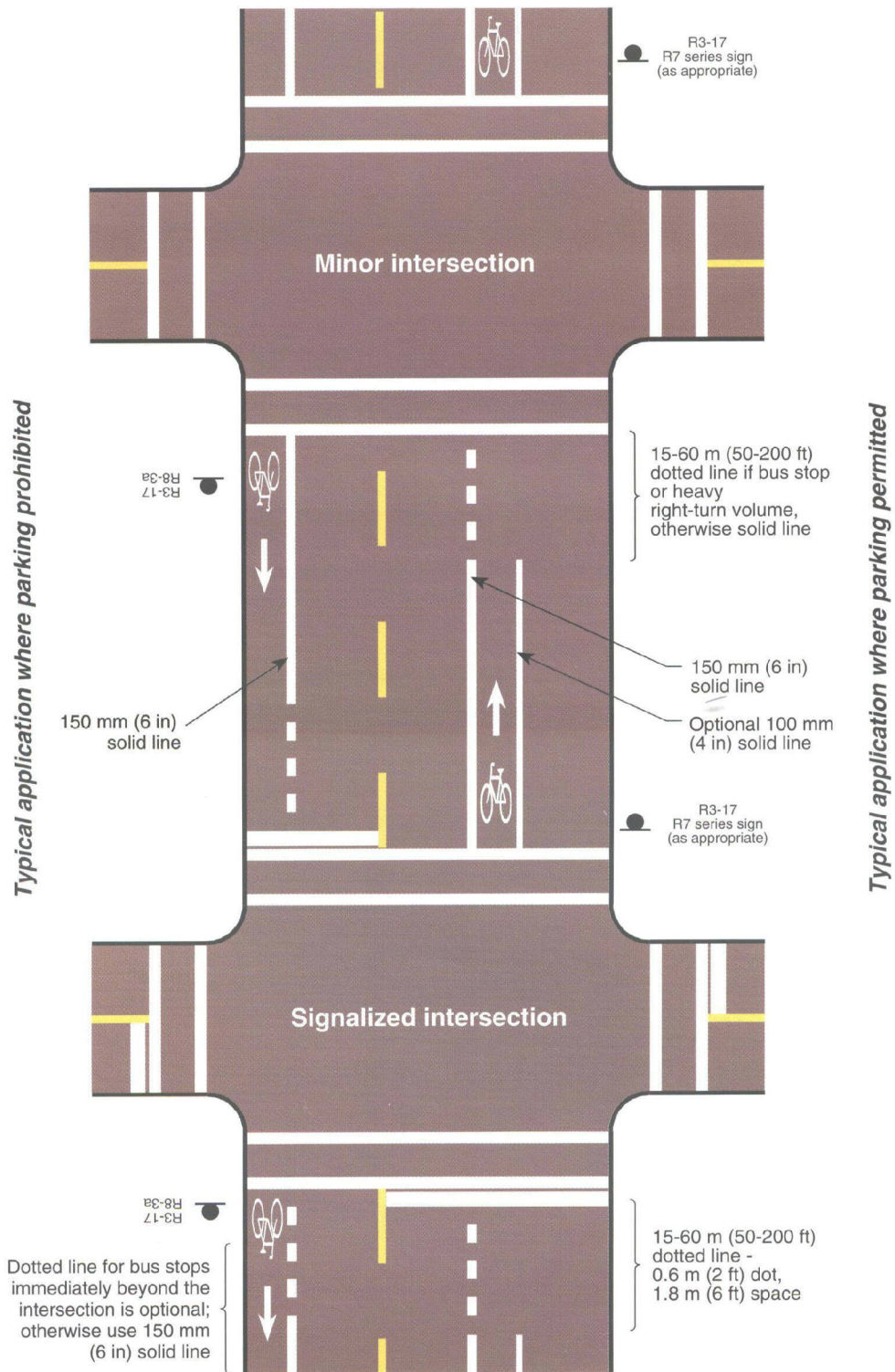
Definition: AASHTO defines a bike lane as “a portion of a roadway which has been designated by striping, signing and pavement markings for the preferential or exclusive use of bicyclists.”²



Design Guidance

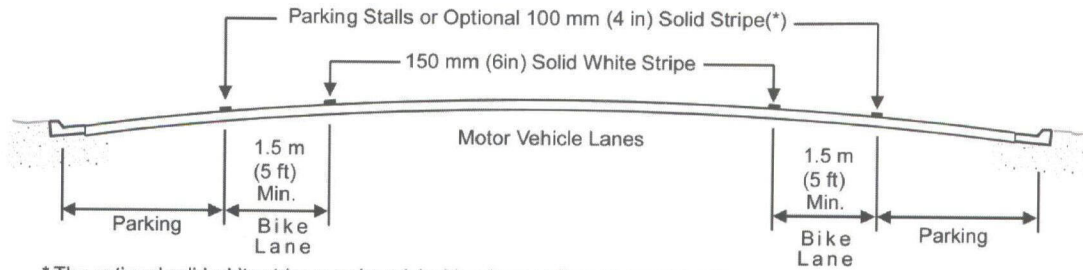
- On two-way streets, a bike lane should be provided on each side of the street (see Figure 2.3.1). Bike lanes are typically one-way facilities that carry bicycles in same direction as motor vehicles.
- Bike lane widths: Roadways with no curb and gutter, minimum 4 feet; roadways with curb and gutter: minimum 5 feet (see Figure 2.3.2 for details). Bike lanes can be six feet or greater where achieving level of service targets or the presence of high turnover parking suggests that more space is needed. Bike lanes of 8 feet or greater may be perceived by motorists to be an additional travel lane.
- Provide a white, 6-inch wide stripe between travel lane and bike lane.
- Provide a white, 4-inch stripe between bike lane and a parking lane.
- Provide bicycle safe drainage grates.
- Minimize location of utility covers in bike lanes (slippery surfaces when wet).
- Signs and pavement markings are standardized in the MUTCD, Part 9 Traffic Controls for Bicycle Facilities.





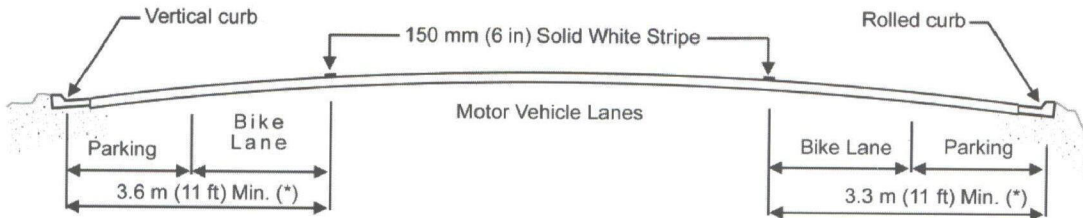
Typical Pavement Markings for Bike Lane on Two-Way Street
(From AASHTO Bike Design Guide)

Figure 2.3. 1 Typical Bike Lane Pavement Markings



* The optional solid white stripe may be advisable where stalls are unnecessary (because parking is light) but there is concern that motorists may misconstrue the bike lane to be a traffic lane.

(1) ON-STREET PARKING

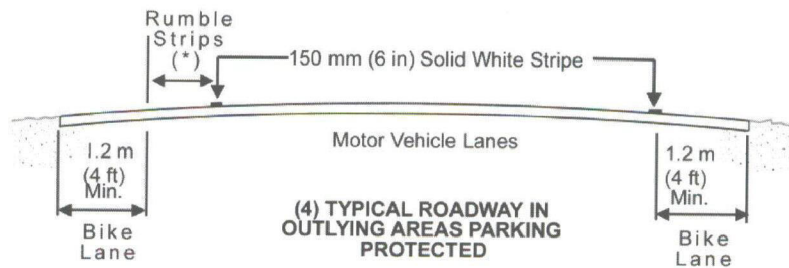


*3.9 m (13 ft) is recommended where there is substantial parking or turnover of parked cars is high (e.g. commercial areas).

(2) PARKING PERMITTED WITHOUT PARKING STRIPE OR STALL



(3) PARKING PROHIBITED



*If rumble strips exist there should be 1.2 m (4ft) minimum from the rumble strips to the outside edge of the shoulder.

Typical Bike Lane Cross Sections

(From AASHTO Bike Design Guide)

Figure 2.3.2 Typical Bicycle Lane Cross Sections

2.4 Shared Use Path Design

Definition: AASHTO defines a shared use path as “a bikeway physically separated from motorized vehicular traffic by an open space or barrier and either within the highway right-of-way or within an independent right-of-way.”³

Location: The Master Plan recommends shared use paths for both in right-of-way and independent right-of-way settings. Along primary arterials such as Route 7 or Route 50 shared use paths may be used as the primary bicycle and pedestrian facility, however in most cases, sidepaths are recommended to supplement on-road bike lanes, wide outside lanes and paved shoulders to provide facilities that will be more attractive to Type B and C bicyclists (Basic bicyclists and Children).⁴ The provision of a shared use path along a major roadway or highway should not be used to preclude on-road bicycling or the provision of paved shoulders that are open to bicycle use.

Safety: Designers of shared use paths adjacent to streets and roads need to be vigilant regarding a safety issues related to sidepaths because motorists often have difficulty spotting pathway users at road and driveway intersections. Sidepaths are located where a sidewalk is typically found. Drivers may not expect bicyclists or skaters, who travel much faster than pedestrians, to be located on sidewalks, creating the potential for conflicts with motor vehicles at driveways and intersections. Moreover, because paths are two-way facilities, the bicyclist may be traveling against the flow of traffic on that side of the road. Studies have shown that bicyclists utilizing pathways at intersections are 4.5 times more at risk than bicyclists utilizing the road at intersections.⁵ For this reason, the design of sidepath crossings of driveways and intersecting roads is critical, and special detail is provided in Chapter 8 of this Toolkit.

Design Guidance

- Recommended minimum width of a shared use path is 10 feet. In Loudoun County, in medium- or low-density areas, sidepaths may be 8 feet wide when a sidepath is provided on each side of the roadway and on-street bicycle facilities are provided as well. These conditions are compatible with AASHTO guidelines.⁶
- A minimum 2-foot side graded area with a maximum 1:6 slope should be maintained adjacent to both sides of the path.
- Slopes greater than 5 percent are undesirable, however slopes of up to 11 percent can be used for limited distances - see chart in AASHTO guide (p. 39).
- Provide adequate sight distance. The AASHTO guide provides formulas for calculating stopping sight distance on vertical and horizontal curves at various operating speeds and friction factors (p. 40).
- Meandering and undulating sidepaths (pathways that weave in and out and up and down along the edge of the right-of-way) are discouraged. While they seem visually interesting, they are annoying to bicyclists and pedestrians who desire a direct and efficient route. They cause navigational difficulties for people with vision impairments. There are circumstances, however, when it is desirable to curve a sidepath: 1) to go around an unmovable barrier or existing tree that should not be removed, 2) to take advantage of an opportunity increase the



separation between the road and the pathway (i.e. a wider buffer), or 3) to bring the shared use path to the proper alignment with a curb ramp and crosswalk at an intersection. This type of occasional shift is acceptable and can be done using gentle curve radii so that pathway users will still perceive the route to be direct and efficient.

- Surface must be smooth and free of defects (bumps, cracks, joints). It is preferable that paths be paved with asphalt, however for aesthetic or maintenance reasons, concrete can be used.



Chapter 3: Standard Roadway Cross Sections

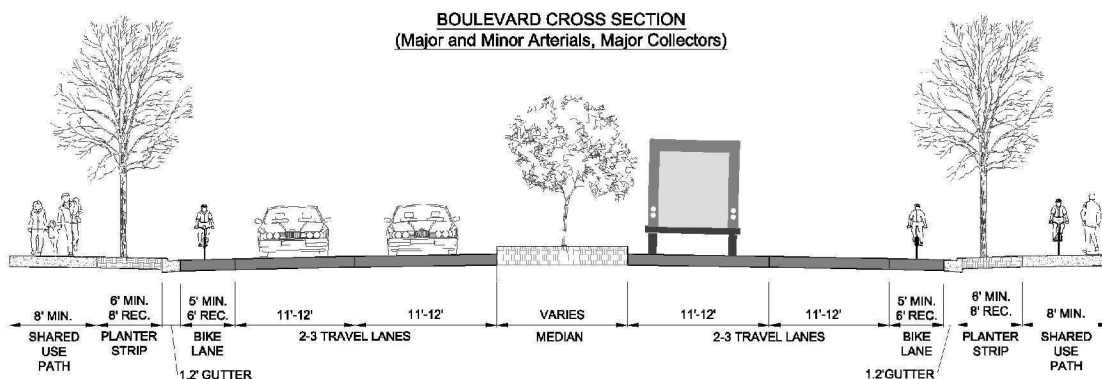
Loudoun County has a variety of roadway cross sections (See Chapter 4 of the Master Plan, Table 4-1). This chapter provides recommended standard cross sections for frequently encountered roadway design conditions within the county. Due to the wide variety of roadway configurations found in the county, not all potential configurations were incorporated into this chapter. As in all cases, proper engineering judgment is required to achieve the proper balance between providing for the needs of motorists, bicyclists, and pedestrians for any given roadway.

These cross sections depict the minimum pedestrian and bicycle accommodations within the roadway cross-section. These accommodations consist of sidewalks, shared use pathways, paved shoulders, bicycle lanes, medians, and planter strips (buffer zones) each of which will provide a balance between the various needs of the different roadway users.

3.1 Boulevards

Loudoun County has many existing and planned multi-lane roads which serve as major and minor arterials and major collectors; roads such as Loudoun County Parkway, Cascades Parkway, Pacific and Atlantic Boulevards, Claiborne Parkway, etc. These roads provide direct access between the major communities within Loudoun and sometimes provide direct connections to neighboring Virginia Counties. Due to the high speeds and traffic volumes on these roads, bicycle accommodations should be located both along the road and adjacent to the road on shared-use paths. As multi-modal boulevards, serving a wide range of bicyclists, pedestrians and motorists, Loudoun's primary arterials and collectors can be streets that are safe, attractive and efficient.

The center curbed and vegetated median is a prominent feature of the boulevard. Studies have shown that curbed median roadways have significantly lower numbers of crashes. At intersections, vegetated medians provide pedestrians with a crossing refuge and they help to visually narrow these wide roadways. The buffer strip between the sidewalks and the roadway create a sense of separation between pedestrians and motor vehicles, which provides a higher pedestrian level of service for the pedestrians walking alongside the roadway. The provision of both on-street bicycle facilities and off-road sidepath(s) ensures that all types of bicyclists are served.



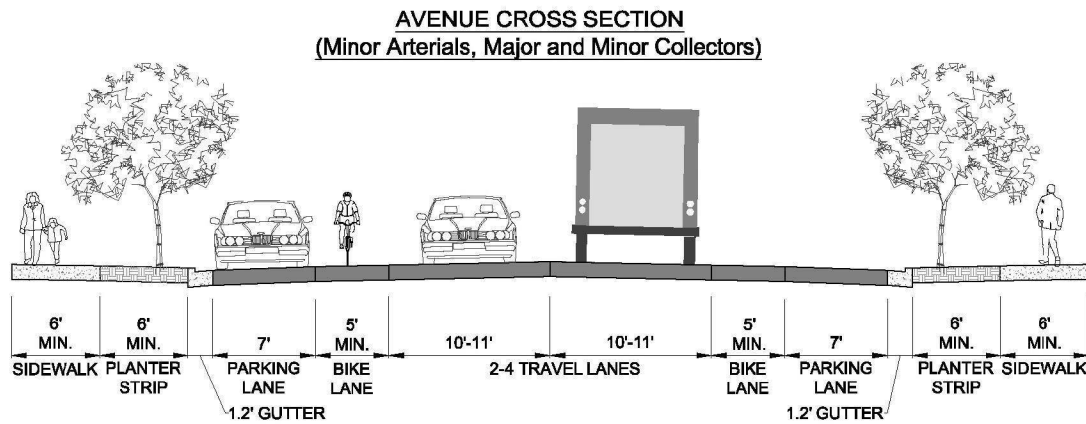
Typical Design Features

- 4-6 travel lanes for motor vehicles.
- Center vegetated median, which can incorporate turn bays as necessary.
- Recommended 6-8 foot wide medians (minimum 4 feet) to provide adequate waiting space for crossing refuge islands.
- 5 to 6-foot bike lanes depending on motor vehicle volumes and speeds to meet BLOS required per Table 4-2 in the Master Plan.
- 6-inch solid white stripe to be located between paved shoulder and travel lane to define bike lane and increase its visibility.
- Recommended 8-foot vegetated buffer (planter strip) between path/sidewalk and roadway. Plant trees in the buffer between sidewalk/pathway and roadway to increase pedestrian level of service and to reduce the apparent width of the roadway. See chapter 2-2 for further discussion.
- 8-foot minimum shared use path provided along both sides of roadway. An alternative cross section provides a 6-foot sidewalk on one side of the roadway, and a 10-foot shared use path on the other side, where development density and the characteristics of adjacent land uses are expected to result in few type-A and B bicyclists seeking access to one side of the road.
- Sidewalks and paths should generally be straight and level, without unnecessary curves or slopes. See previous section for details about meandering sidewalks.
- See chapters 4-7 for intersection accommodations.



3.2 Avenues

Minor arterials and collectors and some major collectors can be built and modified to create avenues that carry medium volumes of traffic and accommodate bicycles and pedestrians as well. The primary difference between these roads and boulevards is that these roads carry less traffic, at slower speeds.

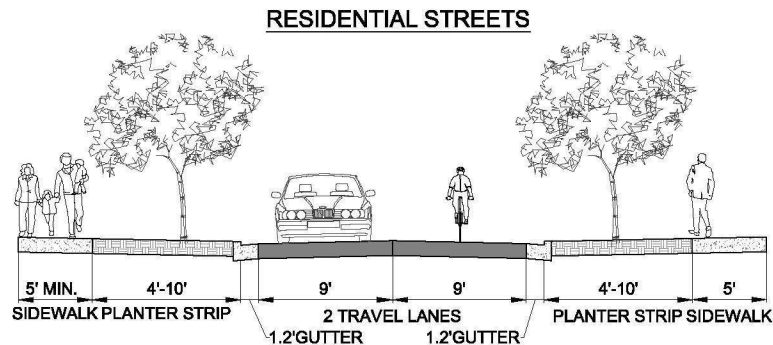


Typical Design Features

- Right and left turning bays provided at intersections in place of parking as needed.
- Provide pedestrian refuge islands at intersections greater than 60-feet in width.
- Provide street trees in the buffer between the sidewalk and road.
- 5 to 6-foot bike lanes depending on actual motor vehicle volumes and speeds to meet BLOS required per Table 4-2 in the Master Plan.
- See Chapter 4 for bike lane design at intersections.

3.3 Residential Streets

These roadways primarily serve residential neighborhoods where roadway speeds are reduced to less than 20 mph. Parking can be provided on neighborhood streets as needed; when provided it should be striped to visually narrow the road.



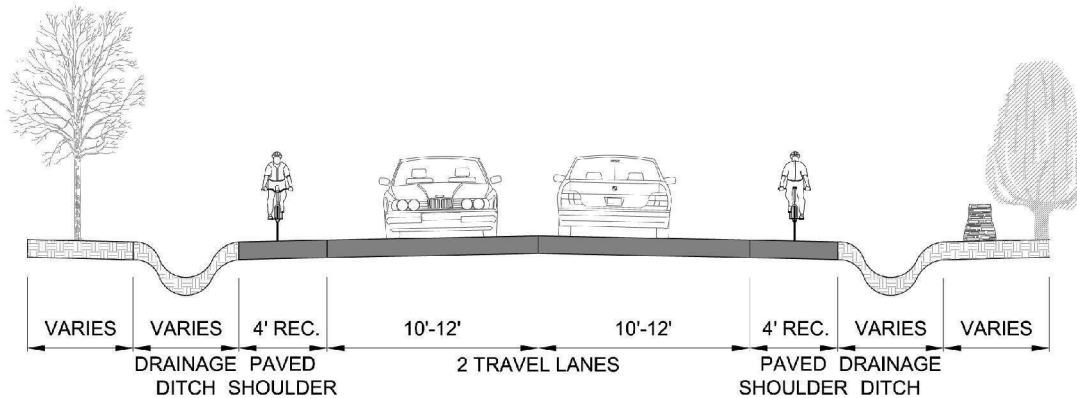
Typical Design Features

- Parking optional – requires wider right-of-way.
- Using narrow travel lanes, motorists' speeds are reduced to approximately 20 mph.
- If wider rights-of-way are used other geometric design measures and traffic calming techniques can be used to keep actual speeds at or near the desired speed limit.
- With low traffic volumes and slow speeds, bicyclists share the road with motorists.

3.4 Rural Roads

There are a wide variety of conditions on Loudoun's rural roads. Bicycle accommodations must be considered in design for safety improvements along these roadways. The design for bicycle accommodations on rural roads should consider the impact to the rural character of the roadway. The variety of road conditions suggests that a variety of designs that would facilitate bicycle and pedestrian use may be desired.

RURAL ROADS



Typical Design Features

- 4-foot paved shoulders are recommended.
- The width of paved shoulder that is needed to meet the BLOS and PLOS required per Table 4-2 will vary, depending on other LOS inputs such as traffic volume, percent of trucks and buses in the traffic mix and speed limit. Therefore, the designer's rule of thumb is *that some shoulder is better than no shoulder, and a wider travel lane is generally safer for bicycles and motor vehicles to share than a narrow one*. While striped shoulders of 2-4 feet are less than the minimum required to designate as shoulder bike lanes, they may provide an adequate minimum BLOS, and make the road eligible for designation as a bike route.
- 6-inch (minimum) solid white stripe to be located between paved shoulder and travel lane to define shoulder area.
- If rumble strips are present, a minimum 4-foot space between rumble strips and edge of pavement should be provided per AASHTO guidelines.

Chapter 4: Bike Lane Design at Intersections

Intersections are the most complex aspect of bike lane design. The majority of all conflicts between motor vehicles and bicyclists take place at intersections. Each intersection design involves compromises between space and access. Intersections require space to be shared between all users; therefore, it is important to define the locations where motor vehicles and bicycles should cross paths with each other. The installation of signs and/or signals, in addition to the physical roadway characteristics (lane width, turn only lanes, crosswalks, striping...etc) provide a method for directing all users through intersections in a manner that reduces or eliminates conflicts between users. The placement of signage and the striping of bicycle lanes through intersections must be coordinated to guide motorists and bicyclists through them in a manner that clearly identifies which user has the right of way at each portion of the intersection.

4.1 General Intersection Design Considerations

- Bicycle Lanes should be aligned and striped to reduce or eliminate conflicts between right and left turning vehicles and bicyclists who are traveling straight or turning (see Figure 4.1.1);
- Facilitate crossing movements in advance of an intersection (i.e. – automobile crossing over bike lane to enter a right or left turn lane or the bicyclists crossing over the automobile travel lane to turn left);
- Utilize dashed striping to indicate automobile or bicycling yield area. Install appropriate signage to indicate which user must yield. The dashed striping locations will vary based upon the turning lane length. The length and location of the dashed striping will determine the amount of yield time and space available for the motorists and the bicyclists;
- Striping and signage at intersections must indicate clearly which users must yield before crossing the other users path;
- Do not install striping across pedestrian crosswalks;
- Utilize dotted guidelines to assist bicyclists turning left on multi-lane roads (see Figure 4.1.2);
- Create as compact an intersection as possible to minimize all crossing distances;
- Provide adequate visibility for all users by following AASHTO sight line guidelines;
- Minimize the use of dual and triple turn lanes;
- Provide adequate lighting as necessary;
- Signal in accordance with MUTCD requirements;
- Install bicycle detectors for intersections that utilize detection devices for signal timing.



The AASHTO bikeway design guide and MUTCD provide numerous lane-striping examples for designers to consider. Two of these examples from the MUTCD are shown below to demonstrate both right and left turn striping options.





Figure 4.1.1 - Typical Bicycle Lane Treatment at a Right Turn Only Lane
(From MUTCD, Chapter 9)

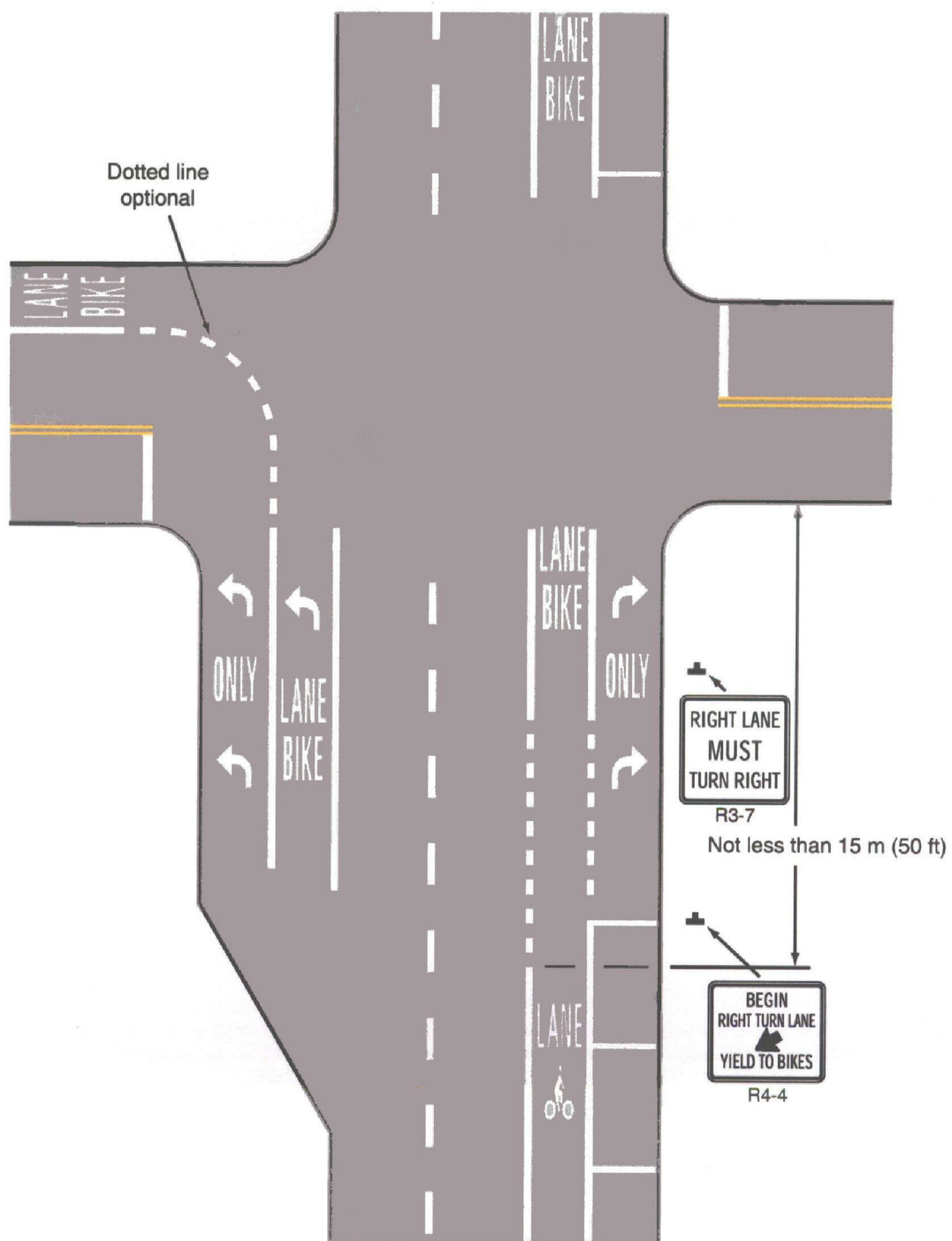


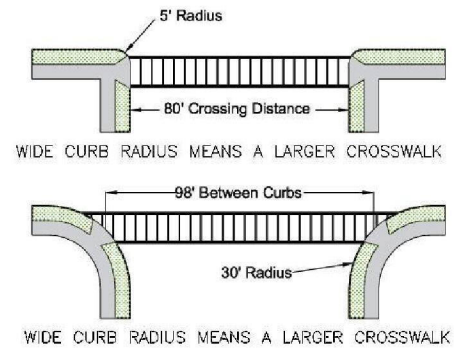
Figure 4.1.2 –Bicycle Lane Striping for Right Turn Lane After Parking and Bicycle Left-Turn Lane (From MUTCD, Chapter 9)

Chapter 5: Pedestrian Crossing Design at Intersections

Pedestrians should be included as “design users” at all intersections where they are legally permitted to cross. The efficiency of truck and automobile movement through intersections must be balanced with safety considerations of pedestrians and bicyclists. This chapter discusses design features that can enhance the safety, comfort and visibility of pedestrians at intersections.

5.1 Pedestrian Crossing Distances

Pedestrian crossing distances should be as narrow as possible to reduce pedestrian exposure time and decrease motor vehicle delay. Tighter turning radii, curb extensions, and median refuges should be used whenever crossing distances exceed 60 feet. In some cases, providing shorter crossing distances and reducing arterial street lane widths can increase intersection capacity for both vehicles and pedestrians, because the signal phase controlling the pedestrian movement (amount of signal time provided for pedestrians to cross the street) can be shortened.



5.2 Intersection Corner Radii

Over one-third of all pedestrian crashes occur at signalized intersections and involve turning vehicles. The frequency and severity of turning-related pedestrian crashes at intersections can be reduced by designing for slower turning speeds, shortening crossing distances, providing adequate lighting, and ensuring sufficient sight distance for both drivers and pedestrians.

Designing corner radii at intersections requires engineering judgment and a context sensitive design approach. Rather than designing for the largest possible design vehicle, corner radii should be designed to be as small as possible, while considering the existing and future volumes and safety of all intersection users.

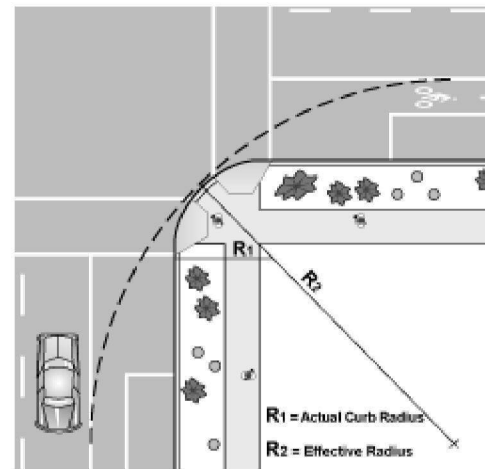


Figure 5.2.1: Effective radius with bike lanes and parking (Oregon DOT)

Large turning radii allow vehicles to turn at high speeds and increase pedestrian crossing distances. Both factors reduce pedestrian safety and comfort. Large radii make pedestrians less visible to drivers, make vehicles more difficult for pedestrians to see, and consume roadway space that can be better used to protect waiting pedestrians. However, at intersections with heavy truck or bus turning volumes, curbs that protrude into the effective turning radius of these vehicles may cause them to damage the curb and other street infrastructure or endanger

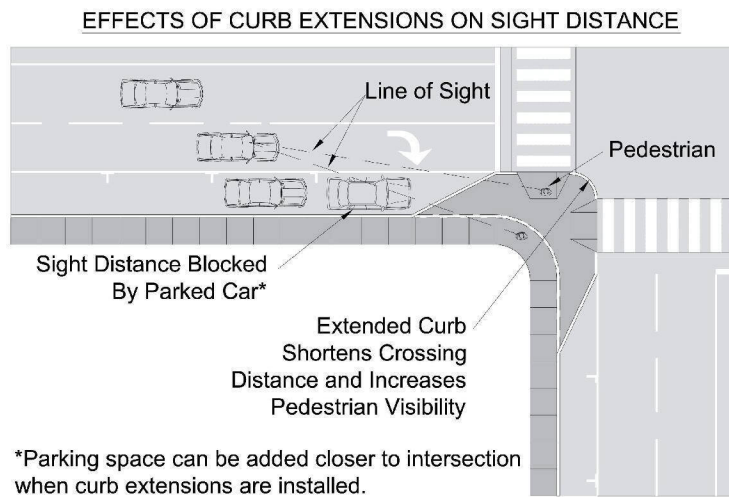
pedestrians waiting on the corner. Therefore, each intersection can be a complex design challenge that must consider a combination of issues.

Corner radius design can sometimes be based on the *effective turning radius*, rather than the *actual* street corner radius (see Figure 5.2.1). The *effective turning radius* is defined as the radius needed for a turning vehicle to clear adjacent parking lanes and move safely into the new travel lane. In locations with on-street parking, bicycle lanes, or shoulders, this can enable the designer to use a smaller corner radius.

In locations with infrequent truck or bus turning movements, a 10 to 15-foot street corner radius is recommended. Using the effective turning radius, the actual street corner radius should be as small as possible while accommodating the appropriate design vehicle. For locations where a large radius is required, triangular crossing islands should be used to shorten pedestrian crossing distances and channelize traffic (see Chapter 7).

5.3 Curb Extensions

Like reduced curb radii, curb extensions provide for enhanced visibility between pedestrians and drivers, greater space for pedestrians waiting to cross the intersection, and less exposure for pedestrians due to shorter crossing distance. Curb extensions can also prevent cars from parking too close to the crosswalk area.



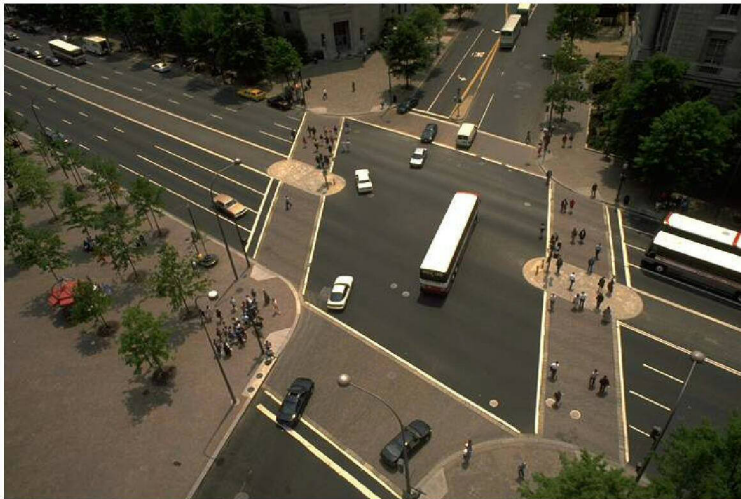
Curb extensions are typically provided only on streets with on-street parking lanes. Curb extensions should not extend into travel lanes. Typical curb extensions extend 6 feet from the curb (the approximate width of a parked car). The turning needs of larger vehicles should be considered in curb extension design (see section 5.2 above).

Curb extensions can also be used at midblock locations to the benefit of the pedestrian (see Chapter 7).

5.4 Pedestrian Islands and Median Refuges

Islands serve three primary functions: (1) channelization – to control and direct traffic movement, usually turning; (2) division – to divide opposing or same direction traffic streams, usually through movements; and (3) refuge – to increase the safety and comfort of pedestrians crossing at intersections and midblock locations. When islands are designed for this last purpose, they are often termed *pedestrian crossing islands* or *median refuges*. When islands are intended to facilitate pedestrian crossings, they should be designed according to the guidance in this chapter, as well as standards that may be provided in local or state guidance documents.

Wide roadway crossings deter pedestrian use. Pedestrian crossing islands break the total crossing distance into two or more shorter segments, depending on how many islands are used. Islands provide a safe waiting area for those who cannot finish crossing a roadway, either because they began crossing late or travel slowly, such as elderly, disabled or child pedestrians.



Example of pedestrian crossing islands used on a multi-lane arterial road.

Photo by Dan Burden

The amount of space that can be provided for waiting in a median refuge or crossing island is determined by the width of the median. For this reason refuge width and median width are considered the same measure.

Refuges 4 feet wide, or greater, have been shown to provide a safety benefit for pedestrians. However, refuges less than 5 feet wide will not provide sufficient space to effectively serve all users. Wheelchair users, people pushing strollers and pedestrians walking

bicycles may not be fully protected by small refuges, for example, standard bicyclists need a minimum of 6 feet in a refuge island. Bike trailers, tandems, trail-a-bikes, recumbents and other long vehicles need 8 to 9 feet to be fully protected. The speed limit on the roadway is also a factor; where the speed limit is 45 mph or greater, the crossing island should be at least 8 feet wide.

For these reasons, a refuge at a typical roadway intersection serving a typical mix of pedestrians is recommended to be 6 to 8 feet wide. The minimum width is 4 feet.

Median refuges and islands serving shared use pathways, or are on major feeder routes to shared use paths, should be a minimum of 6 feet wide, and 8-10 feet is recommended, depending on the volume and make-up of the non-motorized traffic.

Travel lane widths may need to be reduced to 10 or 11 feet in order to meet the minimum width needed for median refuges or islands. Reduced lane widths may also benefit pedestrians by lowering vehicle speeds.

Refuge islands should include curb ramps, or through cuts to ensure accessibility (see Chapter 6 for details). All median refuges curb cuts and ramps should be aligned directly with marked crosswalks and provide a straight and accessible route of travel.

5.5 Crossings and Crosswalks

An intersection crossing is the marked or unmarked extension of a sidewalk or shoulder across an intersection (see Figure 5.5.1). Midblock pedestrian crossing locations can also be marked with crosswalks.

Crosswalks are an essential element of a connected system of pedestrian sidewalks and pathways. Marked crosswalks tell the pedestrian the best place to cross a street and clarify that a legal crosswalk exists at a particular location. They help drivers understand where to expect pedestrians that are crossing the street. They also help pedestrians know what part of the roadway to use when crossing the street.

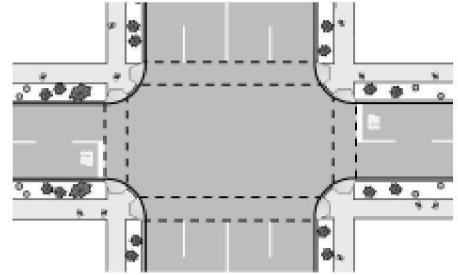


Figure 5.5.1: Unmarked crosswalks (Oregon DOT)

In Loudoun County, marked crosswalks shall be provided across all street approaches to signalized intersections. At uncontrolled locations, such as midblock crossings the addition of a crosswalk should usually be combined with other pedestrian crossing treatments such as short crossing distances, curb extensions, median refuge islands, raised crosswalks, flashing beacons, adequate night lighting, traffic calming, and/or other pedestrian safety treatments (see Chapter 7, section 4.)

Recent advances in Intelligent Transportation System technology include new pedestrian crossing treatments that can enhance pedestrian accommodations and safety as well, such as infrared detection, in-pavement lighting systems, pedestrian countdown signals and audible pedestrian signals (see Section 5.9 and 5.10 and the MUTCD).

5.6 Crosswalk Design

Crosswalks should be 10 feet wide or the width of the approaching sidewalk if it is greater. The standard crosswalk striping treatment for low-volume pedestrian crossing locations is two parallel lines, as shown in Figure 5.6.1. To increase visibility, the MUTCD also offers ladder and zebra striping configurations. Additional guidelines for crosswalk design are found in the MUTCD and current ADA guidance.

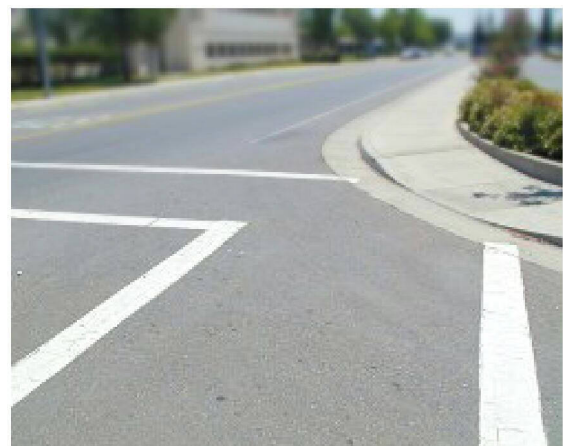


Figure 5.6.1: Standard Crosswalk for Low Volume Pedestrian Crossings

High visibility crosswalks that use a ladder-style marking (see Figure 5.6.2) should be installed in the following locations:

- In locations where a school crossing guard is normally stationed to assist children in crossing the street, and/or at intersections that lie within the walk zone of a school.
- In all locations within 1/4 mile of transit stations, and adjacent to bus stops.
- In legally established mid-block crossing locations (in conjunction with other crossing measures such as warning signs, median refuge, curb extensions, traffic calming, etc.).
- In locations where there is a need to clarify the preferred crossing location when the proper location for a crossing would otherwise be confusing.
- In locations that experience a moderate to high volume of pedestrian crossings.



Figure 5.6.2: High Visibility Crosswalk – there are a variety of ladder-style and diagonal crosswalk marking patterns that are more visible to motorists than parallel lines.

Regardless of the material used for crosswalks, the accessible pedestrian route must be firm, stable and slip-resistant, and reflective (per the MUTCD) for visibility at night. Paving systems that may shift and/or settle should not be used.

5.7 Raised Crosswalks

Raised crosswalks not only benefit pedestrians, but can also be effective traffic calming devices. Raised or speed-table crosswalks enable pedestrians to cross the roadway at curb level, which makes pedestrians more visible to drivers and eases navigation for wheelchair and scooter users the elderly, people pushing strollers and child cyclists. Raised crosswalks are most appropriate in low-speed, pedestrian-oriented environments and for mid-block crossings where the added traffic calming effect is appropriate and desired.

The flat portion of the speed table, used for the crosswalk, should be 10-15 feet wide. Pavement markings should be used in the sloped approaches to increase visibility for motorists. Various crosswalk markings and surfaces can be used. Pedestrian crossing signs should also be used to alert motorists.

5.8 In-Street YIELD TO PEDESTRIAN Signs

In order to increase pedestrian safety and raise motorist awareness, crosswalks may be marked with a special “YIELD TO PEDESTRIAN IN CROSSWALK” sign, which is placed in the center of the road, typically in front or behind the crosswalk (so as not to impede the flow of pedestrians). Note that, while these devices are widely used in the United States, there is currently no standard for these signs in the MUTCD.



The following are basic guidelines for the placement of these signs:

- They are typically installed in areas with significant pedestrian activity, such as a central business district or near a mall or transit station.
- They should not be used on roadways that have a clear width less than 24 feet.
- They can be installed either at mid-block locations or at intersections.
- They should be removable for roadway maintenance.



In-Street “Yield to Pedestrian” signs can help to increase motorist awareness of traffic safety laws.

- They should be placed immediately in front of, or behind the crosswalk; not within the crosswalk.
- They should not be placed on roadways with posted speeds over 35 mph, or in locations that adversely affect motor vehicle turning radii.

The following are basic guidelines for the design of these signs:

- They should have an orange or yellow support device and white graphics panel with a red and black legend, and made with a retro-reflective sign face.
- They should be made of flexible material that will not present a hazard when touched or struck by a vehicle.
- They should not be wider than 14 inches, including sign and support.

5.9 In-Roadway Warning Lights

In-roadway warning lights are a new treatment that has been shown to increase the safety of pedestrians at some unsignalized midblock locations. They are included in Section 4L of the MUTCD. This Chapter provides an overview of their use.

In-roadway lights are used to “warn road users that they are approaching a condition on or adjacent to the roadway that might not be readily apparent and might require the road users to slow down and/or come to a stop. This includes, but is not necessarily limited to, situations

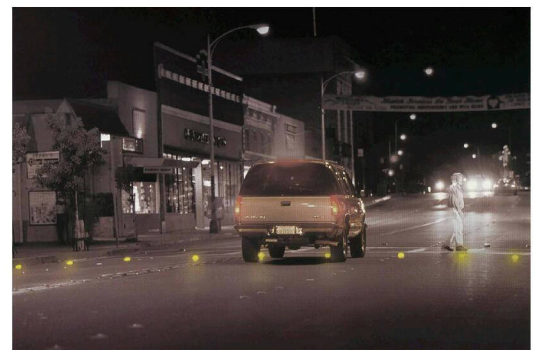


Figure 5.9.1: Yellow in-roadway warning lights help motorists to better see pedestrian crossing locations at night.

warning of marked school crosswalks, marked mid-block crosswalks, marked crosswalks on uncontrolled approaches, and other roadway situations involving pedestrian crossings.”⁷

In-roadway warning lights are used at midblock crosswalks to increase motorist awareness of a pedestrian crossing, or preparing to cross the street. A pedestrian activates the device, either by pushing a button or through automated detection. The flashing yellow signals are imbedded in the pavement on both sides of the crosswalk and are oriented to face oncoming traffic. When the pedestrian activates the system, the lights begin to flash at a constant rate, warning the motorist that a pedestrian is in the vicinity of the crosswalk ahead. The flashing lights automatically shut off after a set period of time, such as the amount of time required for a pedestrian to safely cross the street.

Following are some of the requirements listed in the MUTCD that govern use of in-roadway warning lights:⁸

- They shall not be used at crosswalks controlled by YIELD signs, STOP signs, or traffic control signals.
- They shall be installed along both sides of the crosswalk and shall span its entire length.
- They shall initiate operation based on pedestrian actuation and shall cease operation at a predetermined time after the pedestrian actuation or, with passive detection, after the pedestrian clears the crosswalk.
- The flash rate shall be at least 50, but not more than 60, flash periods per minute. The flash rate shall not be between 5 and 30 flashes per second to avoid frequencies that might cause seizures.

5.10 High-intensity Activated Crosswalk Signal (HAWK)

The **HAWK** (High-intensity Activated crossWalk) signal is a combination of a beacon flasher and a traffic control signaling technique for marked pedestrian crossings. It is a pedestrian activated device and is particularly suited to improving pedestrian crossing safety on multi-lane, higher speed roadways. It can be used at typical 4-way or T-intersections, or at mid-block crossing locations.

The HAWK signal resembles a regular traffic signal. The bottom lens, however, is red, and the signal stays in dark mode until activated by a pedestrian seeking to cross. When activated, the signal phase for the motorist begins with a flashing yellow light that turns to solid yellow, then red. The pedestrian receives a *DON'T WALK* indication during the flashing and solid yellow phases, and a *WALK* indication when the traffic control is solid red. The signal phase ends with an alternating flashing red and *DON'T WALK* for the pedestrian, indicating that the motorist can proceed when the pedestrians have cleared the crosswalk, and ends its cycle by going dark again. The signal is accompanied with *CROSSWALK*, *STOP ON RED* signs and a *PEDESTRIAN CROSSING* sign hung directly over the crosswalk.

The City of Tucson introduced this crossing signal technology coupled with their “Watching Over the Pedestrian Like a Hawk” media campaign, the HAWK system has generated one of the nation’s highest driver yielding rates, increasing compliance from 30 percent, under normal

conditions, to 93 percent over an eight-month study period. This treatment, and a similar one referred to as the *PELICAN crossing*, is profiled in ITE's Traffic Control Devices Handbook (2002 edition).⁹

Chapter 6: Corner Design for ADA Compliance

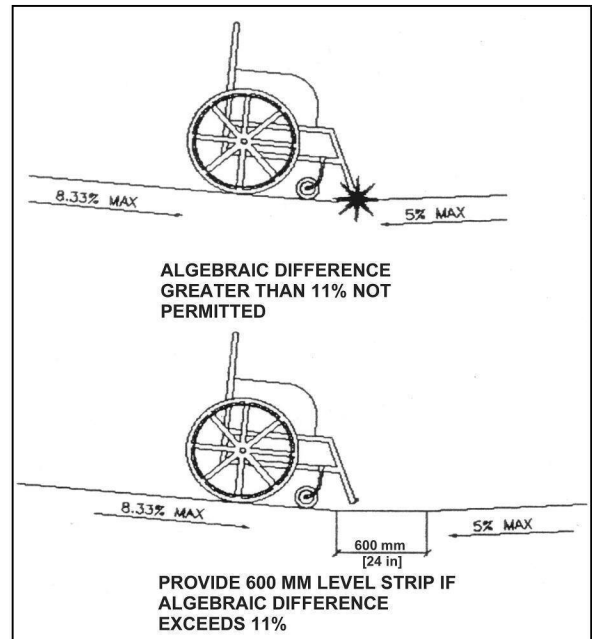
This chapter will provide a standard design for street corners, to meet ADA Accessibility Guidelines (ADAAG). There are a wide variety of curb ramp types that meet ADAAG, however it is best for a community to maintain some consistency in design so that people with disabilities (particularly visually impaired pedestrians) are more easily able to orient themselves. The intersections of shared use paths with sidewalks and roadways also require the installation of ADA compliant curb ramps.

6.1 Curb Ramp Provision Requirements

A curb ramp with a level landing is required wherever a public sidewalk or public pedestrian easement crosses a curb or other change in level. ADA compliant curb ramps are required to be installed during new construction or reconstruction. Examples of places that require the provision of curb ramps include:

- Intersections
- Mid-block crossings
- Medians and islands served by crosswalks
- Alleys
- Accessible on-street parking aisles
- Passenger loading zones
- Driveways

New Construction: At any intersection in the public right-of-way that has at least one corner served by a public sidewalk or a pedestrian access route, all corners of the intersection served by a crosswalk should have curb ramps or flush landings.



Counter Slope Requirements

Reconstruction and Resurfacing: During reconstruction projects and resurfacing projects, regardless of whether the curbs of a highway are being altered, curb ramps and level landings must be installed at all intersections served by sidewalks, and sidewalks shall otherwise be reconstructed as necessary to comply with the ADA.

6.2 Ramp Design

Gutters & Counter Slopes: Gutters require a counter slope at the point at which the ramp meets the street. This counter slope may not exceed 5 percent, and the change in angle must be flush, i.e. without a lip, raised joint or gap. Lips or gaps between the curb ramp slope and counter slope can arrest forward motion by catching caster wheels or crutch tips.

Landings: Landings provide a level area (less than 2 percent cross slope) for wheelchair users to wait, maneuver into or out of a curb ramp, or to bypass the ramp altogether. A level landing 5 feet square is recommended, and 4 feet is the required minimum. The stationary design wheelchair is 48 inches long and the scooter is 52 inches, and the wheelbase widths typically range from 18 inches for manual chairs to 36 inches for scooters and large powered chairs. Where a parallel ramp is used and the level landing separates opposing up-slopes, a 5-foot square landing is necessary to ensure that foot rests do not hang up on the ramp ahead. (See Curb Ramp Types in section 6.3.)

Landings should also be provided at raised medians or crossing islands adjacent to right turn slip lanes (or a level cut-through should be provided).

Flares: Curb ramp flares are graded transitions from a curb ramp to the surrounding sidewalk. Flares are not intended to be wheelchair routes, and are typically steeper than the curb ramp with significant cross-slopes. For pedestrians who have visual impairments, flares may be one of the cues used to identify a curb ramp and upcoming street edge. If the landing width is less than 4 feet, the slope of the flare may not exceed 8.33 percent. If the landing is wider, a flare slope of 10 percent is preferred, to help prevent possible tripping.

Flares are only needed in locations where the ramp edge abuts pavement. A curb edge is used where the ramp edge abuts grass or other landscaping. If the curb ramp is situated in such a way that a pedestrian cannot walk across the ramp sides, flares may be replaced with a curb adjacent to the ramp. Straight returned curbs are a useful orientation cue to provide direction for visually impaired pedestrians.

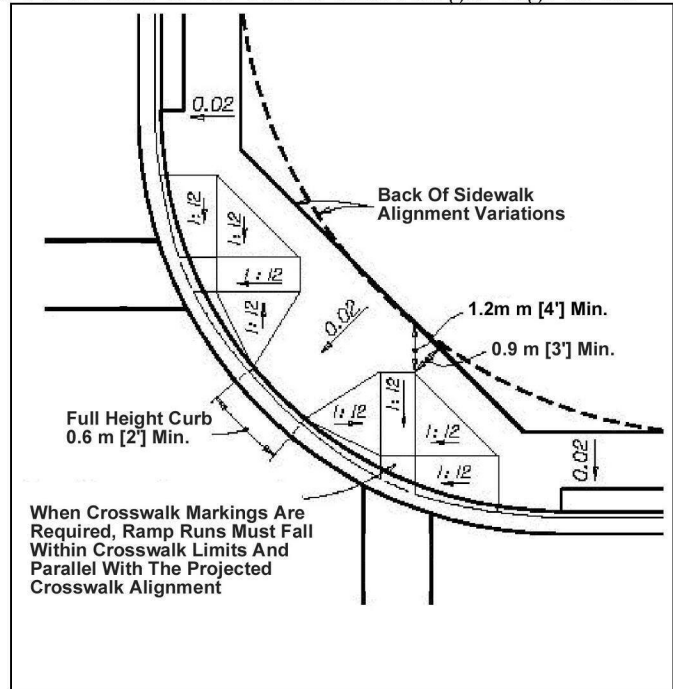
6.3 Curb Ramp Types

The appropriate type of curb ramp to be used is a function of sidewalk and border width, curb height, curb radius and topography of the street corner. Three types of ramps are currently used in street corner designs: perpendicular, diagonal and parallel. In all cases, the ramps should be located entirely within the marked crosswalks (where they exist). Drainage grates or inlets should not be located within the crosswalk area. Grates are a problem for wheelchairs, strollers and those who use walkers.



- Perpendicular Ramps:** These ramps are perpendicular to the curb face. Where the ramp is located on a large curb radius, the designs shown at right should be used so that the ramp can still be parallel to the marked crosswalk. They are generally the best design for pedestrians, provided that a 4-foot landing is available for each approach. If landings are not provided, perpendicular ramps may not be accessible. Perpendicular ramps may not be feasible where drainage grates or inlets are located at the end of each straight edge of the curb, and a diagonal ramp may be required.

Where the sidewalk is too narrow to accommodate a landing, alternatives include a gradual lowering of curb height on the approaches to the corner, purchasing or obtaining an easement from the adjacent property to increase the sidewalk area. Where curb parking exists, constructing a curb extension can also create the sidewalk space needed to install a standard ramp. (See Curb Extension Design)

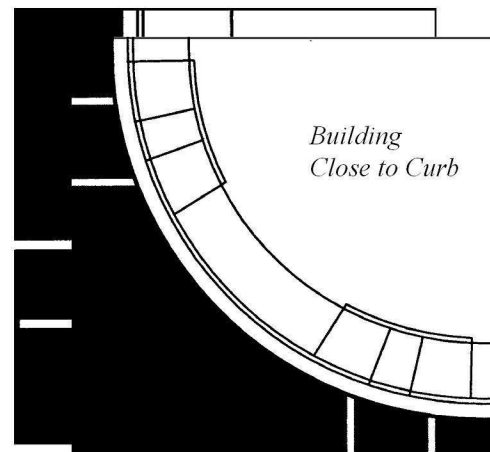


Perpendicular Ramps with Separate Landing Areas

- Parallel Ramps:** Parallel ramps are used where the available space between the curb and property line is too tight to permit the installation of the perpendicular ramp design that includes a 4-foot square landing area at the top of the ramp. Parallel ramps bring the entire sidewalk down to the street grade using a slope that is parallel to the curb line rather than perpendicular to it. A minimum 4-foot landing is required between the two ramps; the landing at the street grade should have a 2 percent drainage slope to the gutter. Detectable warning strips are needed at the curb line between the two ramps. Guide strips along the crosswalk lines may be considered to give guidance to visually impaired pedestrians, since the ramp slope is no longer parallel with the crosswalk. This is similar to the recommended treatment for driveway intersections on streets with limited rights-of-way. (See section on Driveways)

A drawback to parallel ramps is that sidewalk users desiring a through travel path (not using the crosswalks) must negotiate two ramp grades, because no bypass sidewalk space is available. In some cases, reducing the curb radius and recapturing a portion of the intersection for an expanded sidewalk can permit the construction of perpendicular ramps.

- Diagonal Ramps (not recommended):** Diagonal ramps are single perpendicular curb ramps that are located at the apex of the corner. They often



*Diagonal Parallel Ramps
reco*



require pedestrians to enter the intersection prior to entering a crosswalk. This creates additional exposure for the pedestrian. They also create problems for visually impaired pedestrians by aiming them away from the crosswalk. When used, an additional clear level space should be marked as a part of the crosswalk at the base of the ramp to give pedestrians space clear of through traffic to maneuver into their desired crosswalk. This clear space should be a minimum of 4 feet from the edge of the ramp and may not extend into a travel lane. These ramps also require a 4-foot landing at the top of the ramp.

Although diagonal ramps are typically less costly than perpendicular ramps, they increase the potential of vehicle-pedestrian conflicts because of the increased likelihood of vehicles encroaching into the clear space area. Diagonal ramps may not be used where drainage grates or inlets are located at the apex of the curb radius. For these reasons, where space is available, new construction should include two perpendicular (or parallel) ramps rather than a single diagonal ramp. When practicable, existing diagonal ramps should be retrofitted with two perpendicular ramps, and/or consideration given to the addition of curb extensions.

6.4 Curb Ramp Placement

Intersections may have unique characteristics that can make the proper placement of curb ramps difficult, particularly in retrofit situations. However, there are some fundamental guidelines that should be followed:

- Perpendicular ramps should be built 90 degrees to the curb face and their full width at the toe (exclusive of flares) must be within the crosswalk. Aligning the ramp to the crosswalk will enable the visually impaired pedestrian to more safely navigate across the intersection and exit the roadway on the adjoining curb ramp.
- Curb ramps need to avoid storm drain inlets, which can catch wheelchair casters or cane tips.
- Curb ramps need to be adequately drained. A puddle of water at the base of a ramp can hide pavement discontinuities. Puddles can also freeze and cause the user to slip and fall.
- Curb ramps must be situated so that they are adequately separated from parking lanes. Regulatory signs and parking enforcement can help prevent vehicles from blocking or backing across a crosswalk or curb ramp. Even better, curb extensions physically prevent parked cars from encroaching into the curb ramp.



In cases with large turning radii, where the radius cannot be made smaller, it may not be possible to align the ramp run entirely parallel to the crosswalk and still be perpendicular to the curb face. In these cases, it may be possible to install two perpendicular curb ramps aligned parallel to the crosswalk and by introducing a short landing at the bottom of the ramp (see Figure 6.4.1). This will avoid directing visually impaired pedestrians into the intersection.

If a perpendicular approach is not provided, pedestrians who use wheelchairs face a change in cross slope, with only one wheel in contact with the ground.

6.5 Detectable Truncated Domes

To ensure safety for vision impaired pedestrians at intersections with curb ramps, detectable warning devices should be used to provide visually impaired pedestrians a reliable cue that they have arrived at an intersecting street. In the absence of a definitive cue (e.g., a curbed sidewalk at the sidewalk/street boundary), it becomes much more difficult for pedestrians who are visually impaired to detect streets. When visually impaired pedestrians do not encounter a curb at the end of a block, they must rely on multiple clues, which when taken together, indicate they have come to a street. They may detect a change in slope, which could be a curb ramp, a change in terrain or a broken sidewalk. The end of a building line or grass line may suggest that there is a street directly ahead. Changes in sun and wind are also clues. However, none of these clues, by themselves, confirm the presence of an intersecting street. One of the most reliable clues, when it is present, is the sound of traffic on the intersecting street. But intermittent traffic on a wide street can be a misleading cue and vision impaired persons may also be hearing impaired.

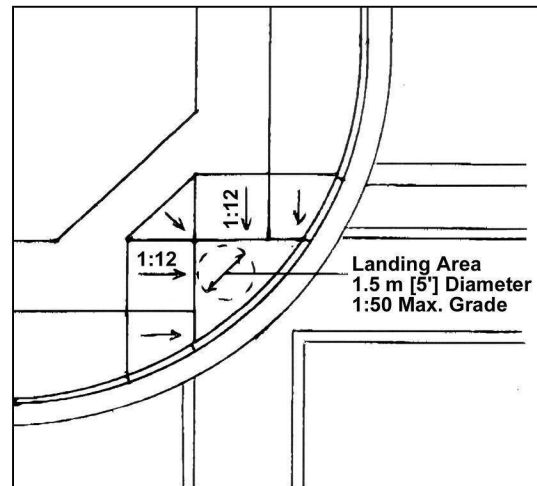
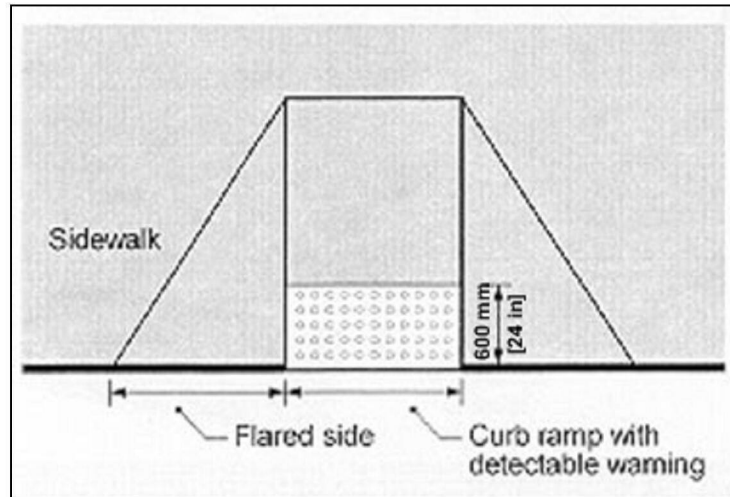


Figure 6.4.1: Perpendicular Ramps with Single Landing Area

To ensure safety for vision-impaired pedestrians, detectable truncated dome warnings should be included in each connection to a street crossing to mark the street edge.

A detectable warning is a standardized feature built in or applied to walking surfaces to warn visually impaired people of hazards on a circulation path (see Figure x). Detectable warnings are unique and standardized features that alert visually impaired pedestrians to the presence of hazards in the line of travel, indicating that they should stop and determine the nature of the hazard before proceeding further.

ADAAG specifies that detectable warnings shall consist of raised truncated domes with a diameter of nominal 0.9 inches, a height of nominal 0.2 inches and a center-to-center spacing of nominal 2.35 inches and shall contrast visually with adjoining surfaces, either light-on-dark or dark-on-light. The material used to provide contrast shall be an integral part of the walking surface, and should contrast visually with adjoining surfaces by at least 70 percent.¹⁰ The *Draft Guidelines for Accessible Public Rights-of-Way* modified the configuration and placement of the detectable warnings; they are to be installed in a 24-inch strip, 6-8 inches back from the curb face for the full width of the ramp or walk (see Figure 6.5.1).¹¹



Commonly used textured surfaces, such as grooves, crosshatching, exposed aggregate, or other treatments, may seem to be a detectable surface, but should not be substituted for the standard ADAAG detectable warning treatment. While these or similar surfaces may be useful to prevent slippage on ramps and sidewalks, they do not meet ADAAG specifications for detectable warning devices and are not approved to mark the street edge. Moreover, use of blended curbs, roll curbs and depressed corners should be avoided because they do not provide cues to the presence of the street.

Figure 6.5.1: Recommended detectable warning treatment — Detectable Truncated Domes (slight modification to the drawing is needed).

Chapter 7: Pedestrian Crossing Design in Special Situations

A variety of free flow turning movements are permitted in Loudoun County. Free-flowing turning movements are designed to maintain and increase motor vehicle speeds and flow, and reduce congestion due to conflicting turning movements; however, they often make pedestrian crossings difficult and discourage pedestrian travel. For example:

- ❑ In free flow turning areas, pedestrians with visual impairments and children who have difficulty judging adequate gaps in traffic may not be able to find an appropriate time to cross a free-flow turning lane.
- ❑ In the case of separate right turn lanes, drivers must look left before merging into the flow of traffic and may fail to see pedestrians who are crossing from the right.
- ❑ At expressway entrance ramps, drivers typically concentrate on accelerating and merging into higher speed vehicle traffic and may not be scanning for pedestrians, or are in a position not well suited to stopping or avoiding a pedestrian collision.

The decision to allow free-flowing movements should be carefully considered, in full recognition of the crossing difficulties it will create for pedestrians and bicyclists. Unless unusual circumstances exist, in areas where pedestrians are expected or desired, free flow turning movements should be avoided, or modified in design to ensure maximum possible pedestrian safety.

7.1 Dual Left-Turn Lanes

Double and triple left turn lanes in the County are designed as “exclusive-only” left turn signals. Permissive left turns are not permitted at these intersections; therefore turning movements do not conflict with pedestrian crossings. However, double and triple left turn lanes significantly add to pedestrian crossing distances and the amount of time that pedestrians are exposed in the roadway, and therefore decrease pedestrian safety and deter pedestrian traffic. For this reason, dual turn lanes should be used sparingly, and other solutions should be found in locations where moderate volumes of pedestrian traffic are expected. Median refuges and crossing islands should be a standard component of intersections with dual turn lanes, where crossing distances exceed 60 feet, and an additional median refuge may be needed to separate multiple through travel lanes from multiple left turn lanes.

7.2 Separate Right Turn Lanes

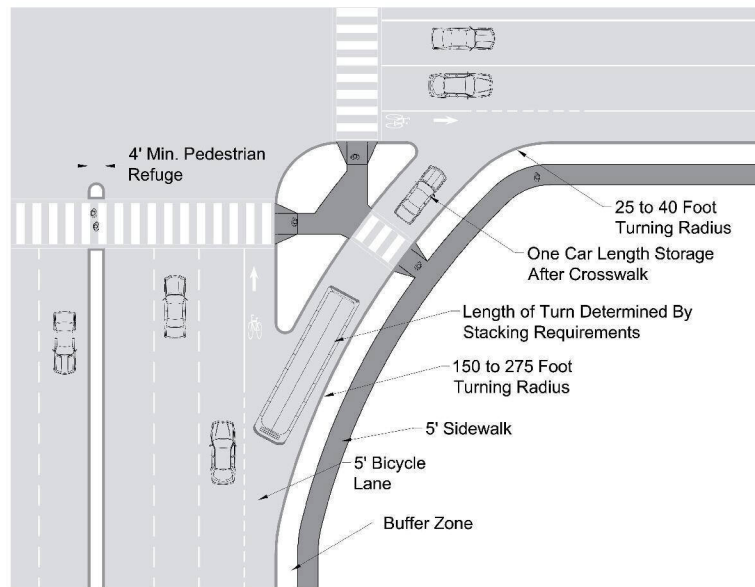
At intersections where a wide corner radius is used, dedicated right turn lanes can be separated from other lanes with a triangular crossing island. This crossing island serves a dual purpose of channelizing traffic and providing a pedestrian refuge (see Figure 7.2.1).

Separate right turn lanes should be designed so that the driver’s attention is first focused ahead and to the right, on the crosswalk, before looking left to complete the turn and merge. This design requires the turn lane to exit the roadway as straight as possible and to enter the receiving roadway at an angle as close to perpendicular as possible (see Figure 7.2.1). The crosswalk



should be placed towards the approach end of the island so that crossing pedestrians are at a location where drivers are more likely to see them. The turning lane width should be minimized (to accommodate the typical traffic, not the infrequent large truck or bus) to slow vehicles and shorten pedestrian crossing distance. Signals, stop signs, or yield signs should be used to ensure that pedestrians have a sufficient gap with time to safely cross; pedestrian warning signs may increase driver awareness of pedestrians.

FIGURE 7.2.1: A slip lane designed at the proper angle, as shown on the right side of the intersection above, provides the driver with greater visibility of pedestrians. The lane on the left creates a higher speed, lower visibility right turn.



7.3 Driveway Design

Driveways are frequent locations for vehicle/pedestrian collisions, and can greatly increase pedestrian discomfort when they are poorly designed. Limiting driveway movements (right-in/right-out only), using shared driveways, and closing driveways can improve conditions for pedestrians.

In commercial areas at unsignalized driveways, conventional driveways¹² are preferred over access points that resemble street intersections, because the pedestrian right-of-way is established more clearly and vehicles must turn more slowly into and out of the driveway. The sidewalk should remain at grade and be made of the same surface material across the driveway, so motorists know they are crossing a pedestrian access route.

If driveway intersections are designed to resemble street intersections, the sidewalks should terminate at curb ramps (per current accessibility guidelines), and pedestrian crosswalks should be provided. Where warranted, pedestrian signals should be installed.

As with standard intersections, vehicle turns can be slowed at signalized driveway entrances by using a small curb radius (15 feet or less), depending on volumes and the size of delivery trucks that the driveway serves. In addition, driveway width should be made as small as possible. Wide driveways allow faster turns and more exposure to pedestrians.

The intersection of driveways and sidewalks can have some of the most severe cross slopes for sidewalk users. Sloped driveway entrances can cause wheelchair users to lose directional control, veer downhill toward the street and potentially tip over. Therefore, several solutions are recommended:

- ❑ At locations with a landscape buffer between the sidewalk and the street, provide a level path of pedestrian travel (as an extension of the regular sidewalk) through the driveway cut, and resume the driveway slope within the landscape buffer.
- ❑ Install a structure similar to a parallel curb ramp that lowers the driveway crossing to the grade of the street (see Figure 7.3.1). Although this solution is preferable to a severe cross slope, it can create steep grades on both sides of the driveway and can cause drainage problems on the landing.

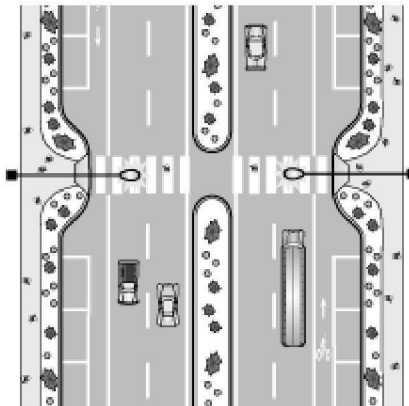


Figure 7.3.1: Alternative driveway design – entire driveway width is depressed.

7.4 Mid-block Crossing Treatments

Midblock crossings are a necessary pedestrian movement in many urban, suburban and rural locations. Pedestrians tend to walk in a path that represents the shortest distance between two points. A variety of settings that are typical in Loudoun County can generate mid-block pedestrian crossing traffic, including the following:

- ❑ Midblock crossings can occur at an apartment complex located across the street from a bus stop or an entrance to a shopping center.
- ❑ The desire to cross mid-block can be generated by the pattern of traffic flow created by timed traffic signals, which produce highly reliable gaps in one direction at a time, improving crossing safety. This is especially true if a median is present. Mid-block crossing locations eliminate the pedestrian hazard of turning vehicles, which complicate busy intersections and increase pedestrian unease and perception of traffic danger.
- ❑ Desire for midblock crossings is generated when the distances between blocks and/or signalized intersections are long.
- ❑ Mid-block crossings are often necessary to accommodate shared use pathway crossings, especially when these paths are located on abandoned railroad alignments or stream corridors that cross roads away from existing intersections.



Mid-block curb extension with median and illumination (Oregon DOT)

Accommodations for mid-block crossings should be carefully considered, because a poorly designed mid-block crossing will violate driver expectance and could cause safety problems for pedestrians. Since no two mid-block crossings are alike, there is no single standard design. Engineering judgment must be used, based on the design principles described throughout this manual. Design issues that should be considered at midblock crossings include the following:

- ❑ Adequate sight distances both from the pedestrian and motorist's perspective.
- ❑ Need for a pedestrian-activated signal, based on a gap analysis.
- ❑ Possible need for *HAWK* pedestrian crossing signals (see Chapter 5).
- ❑ Potential for shortening crossing distance, using curb extensions and/or median refuges (see Chapters 5 and 6)
- ❑ High-visibility crosswalk marking treatment.
- ❑ Adequate signage, possible use of yellow-green warning signs.
- ❑ Appropriate use of traffic calming as needed to reduce excessive motor vehicle speeds in advance of the midblock crossing.
- ❑ Use of shared use pathway crossing treatments (see AASHTO Bikeway Design Guidelines and Chapter 8).

Additional guidance can be obtained from a recent Federal Highway Administration report on crosswalks at uncontrolled locations: *Safety Effects of Marked vs. Unmarked Crosswalks at Uncontrolled Locations: Executive Summary and Recommended Guidelines (FHWA-RD-01-075)*.

Mid-block crossings at uncontrolled locations: The Federal Highway Administration has developed guidelines for crosswalk marking at uncontrolled midblock crossings and intersections.¹³

Mid-block signals: When warranted, midblock signals should be installed proactively on new roadways or when new developments are constructed, and retroactively on existing roadways. Pedestrian compliance with signals will be higher when a timely response is given after the activator button is pushed. While this level of response is not always achievable, pedestrian wait time should be reduced as much as possible. When pedestrians recognize that the signal will reduce their wait time, it is likely that they will use the crossing and obey the signal. When there are other traffic signals nearby, the midblock signal should be coordinated with them. If the traffic signals are on progression, the design of the signal timing and cycle length should include consideration for minimizing pedestrian wait time.

On wide streets with medians, midblock signals may be timed to enable pedestrians to cross the entire width of the roadway in one pedestrian WALK phase (both directions of travel), or each leg may be designed to be activated separately (see *PELICAN crossing*, in ITE's Traffic Control Devices Handbook (2002 edition)).¹⁴ In either case, accessible pedestrian push buttons, and appropriate signage should be provided in the median so that pedestrians can activate or reactivate the pedestrian WALK interval to complete the crossing.

Mid-block crossing illumination: Lighting is essential for making pedestrians visible to motorists, especially at midblock locations. If lighting is not provided along the entire length of a street, it should be provided at a midblock crossing. In general, crosswalks should be provided with additional illumination producing from 1.5 to 2 times the normal roadway lighting level.



Mid-block crossing barriers: Prohibiting, or erecting barriers to eliminate midblock crossings is often counter-productive, and may result in pedestrians crossing streets in a less-than-safe manner and at multiple mid-block locations. Barriers often fail to deter pedestrian crossings, despite the fact that these crossings have been made illegal. The decision to prohibit pedestrian crossings should be carefully evaluated on a case-by-case basis, in full consideration of the likelihood that crossings may still occur and may be justified considering the length of the detour a pedestrian would otherwise be required to take. This evaluation should consider the alternatives with the goal of providing the most convenient and safe pedestrian route possible, given the constraints of the site. Moreover, any installation of median barriers to prevent pedestrian crossings should always be accompanied by other treatments to safely accommodate pedestrian crossings as near as practicable to the point where the barrier has been installed.



Chapter 8: Shared Use Path/Roadway Intersection Treatments

The intersection between shared use paths and roadways are the most important element of shared use path design. Pathways are typically designed to carry two-way bicycle and pedestrian traffic. This causes a conflict with motorists who are expecting bicyclists to be following traditional traffic patterns. For stop sign controlled or uncontrolled intersections, motorists must look for pathway users traveling from both directions before proceeding to cross the path. To avoid conflicts between motorists and pathway users it is critical that the intersection design provides clear direction to all users. Right-of-way assignment must be identified for each user and the geometry of the intersection needs to provide maximum sight distance while minimizing all crossing and turning movements. Every intersection is unique, and each requires engineering judgment to create a functional and safe intersection for all users.

There are three general classifications of shared use path crossings of roadways: adjacent, midblock and complex crossings. Complex crossings can involve the diagonal crossing of intersections or of multiple roadways. Midblock crossings of roadways should occur as close to 90-degrees as possible to maximize sight distance for all users. Detailed guidance on midblock crossings is provided in the MUTCD and the AASHTO bikeway design guide. These resources provide less guidance for adjacent paths crossings, and thus the focus of this chapter on that topic.

8.1 Adjacent Path Crossing of Intersecting Roadway

Where a shared use path is located adjacent to a roadway it is often referred to as a parallel path or sidepath. Parallel path crossings occur when the road the path is adjacent to is intersected by another road. Parallel path crossings refer to the path crossing of the intersecting road. These intersections can be T- or four-way intersections.

The effectiveness of each crossing depends on a number of factors, including the type of traffic control employed, the assignment of right-of-way, the location of the shared use path, and the available sight lines. The AASHTO bikeway design guidebook and the MUTCD manual provide adequate guidance on some of these factors.

Location and Design: To increase awareness of pathway users and motorists presence of each other, the intersection of the pathway should be located close to the parallel roadway, while maintaining a recommended 5 foot buffer. The following additional guidelines are also recommended (An example intersection is shown in Figure 8.1.1):



Pavement marking where pathway users have the right-of-way at the road intersection, Rockville, Maryland.

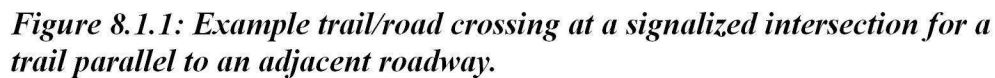
- ❑ If the trail is designed with a large buffer (15-50 feet) between it and the parallel road, the trail should be gently curved to a position closer to the road as it approaches the intersection so that the path crosses in front of the stop line for vehicles on the perpendicular road and in clear view of parallel road motorists.
- ❑ Remove potential visual and other obstructions to improve visibility per the AASHTO sight triangle guidelines.
- ❑ Curb turning radii should be minimized to decrease motorists turning speeds (15-foot radii recommended).
- ❑ Determine which travelway has the through right-of-way (motor vehicles or path users) and sign/signal per MUTCD. Warrant studies for signalization may treat bicyclists as vehicular traffic or pedestrian traffic.¹⁵ Consider provision of signal actuators or bicycle detection devices if signals are installed. Ensure that signal activators are conveniently located for bicyclists to use.
- ❑ Provide a median pedestrian refuge area for crossings larger than 60 feet. Provide 8-10 foot recommended refuge length (6 foot minimum) to accommodate the wide variety of users found on multi-use trails;
- ❑ Bollards should generally not be used to prevent unauthorized vehicle usage of paths that are adjacent to roadways.
- ❑ Provide enhanced lighting at the intersections.

Signalization and Traffic Control:

- ❑ Consider prohibiting motor vehicle “right turns on red.”
- ❑ Consider prohibiting permissive left turns that may conflict with trail crossing movements.
- ❑ Signal timing should allow adequate crossing time for pathway users.



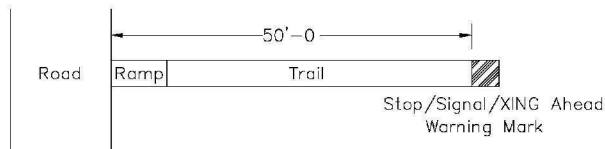
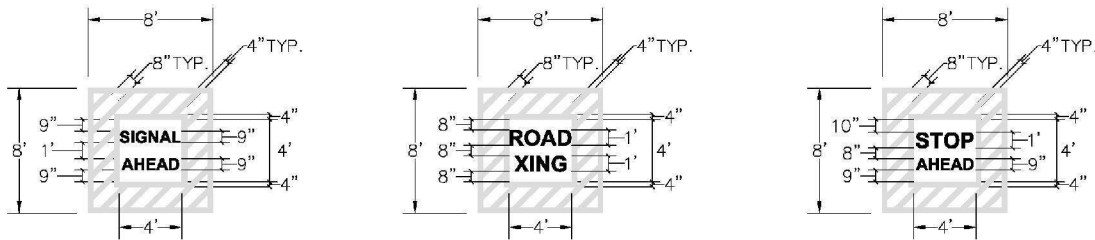
(Crossing Dominant Street)



- ❑ A *SIGNAL AHEAD* marking tells the pathway users that they are approaching a signal-controlled intersection. Actuator buttons and/or detectors can activate the signal for the pathway users waiting to cross. The signal timing preference should reflect the needs of the predominant users in accordance with MUTCD warrant study policy.
- ❑ A *ROAD XING* marking warns pathway users of the upcoming crossing. It is critical that adequate sight distance be maintained.



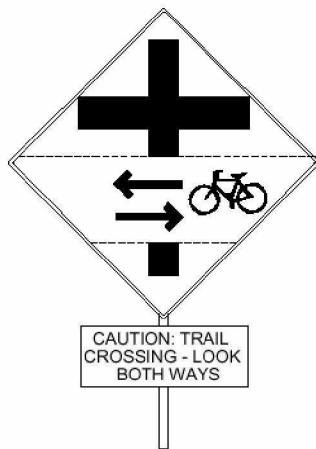
- ❑ A *STOP AHEAD* marking tells the pathway users that they do not have the right-of-way at the upcoming crossing.



Road Xing Markings are to be placed 50' back from the end of the curb ramp/beginning of road xing

Trail Crossing Signs

The following special signs are recommended for trail crossings.



- ## ❑ Perpendicular Approaches

The sign at left should be placed at each perpendicular approach to an intersection trail crossing. This sign warns motorists of the presence of the trail crossing at the intersection.

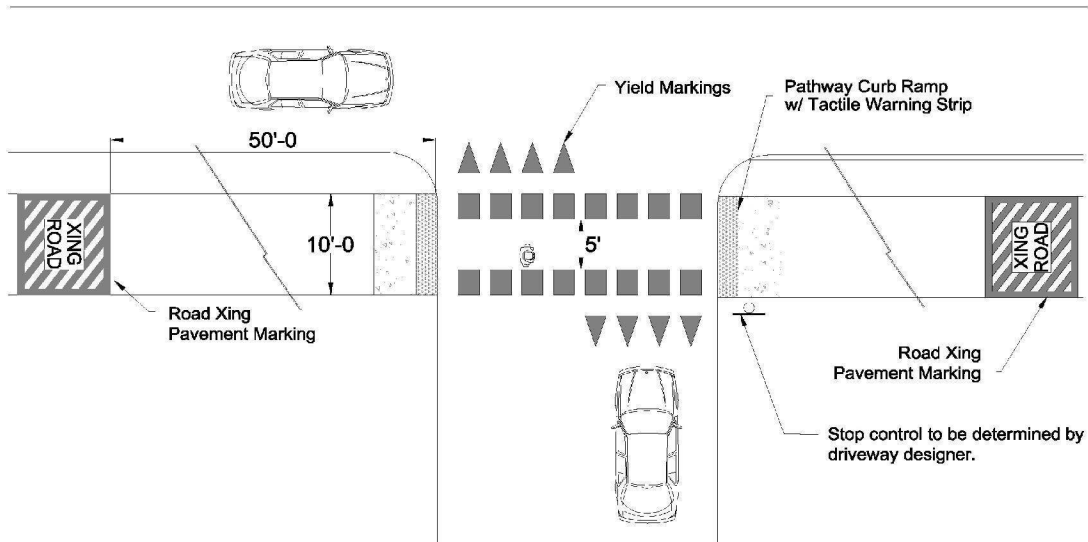
- ❑ Parallel Roadway Approaches

For roadways parallel to the intersection trail crossing, the sign at left should be used. This sign indicates to the motorist that he may encounter trail users during a right turn movement. In situations where the trail user has the right of way, different signs or language should be considered that indicate the driver must yield to pathway users.

8.3 Driveway Intersections

Driveways require the further consideration of entrance ramp placement and automobile yielding and stop control designation. A suggested driveway intersection design is shown below. This detail is designed to give the pathway user the right-of-way. Motorists must yield to all pathway users that are approaching or within the crosswalk area. The distinctive pavement markings are designed to clarify this right-of-way assignment.





Location and Design

Driveway intersections are similar in principal to parallel path intersections. To increase awareness between pathway users and motorist, the intersection of the pathway should be located close to the parallel roadway upon approach to the driveway intersection. (See Section 8.1) Further design considerations include:

- ❑ Remove all obstructions and vegetation to improve visibility per the AASHTO sight triangle guidelines;
- ❑ Curb turning radii should be minimized to decrease motorists turning speeds; radii of 15-feet or less are recommended);
- ❑ Provide pedestrian refuge area for crossings larger than 60 feet. Provide recommended 8-10 foot (minimum 6-foot) refuge to accommodate wide range of trail users;
- ❑ Provide ADA compliant curb ramps that are the same width as the shared use path (See Chapter 6 for curb ramp details). The transitions should be smooth.

Signalization and Warning Signs

- ❑ Pavement markings and signs should warn motorists and pathway users of upcoming intersection. The markings and signs should clearly mark stop and/or yield responsibilities for path users and motorists.
- ❑ Yield markings (triangles) should be placed alongside the pathway to provide a visual cue to motorists to look for pathway users before crossing pathway. Distinctive crosswalks should be considered to provide a uniform and easily identifiable driveway intersection crossing.¹⁶
- ❑ In addition to “Stop” or “Yield” controls for motorists, consider the placement of a sign that depicts multi-directional trail use as shown at right to warn motorists of the trail crossing. This sign is based off the State of Maryland Hiker Biker Trail Crossing Sign, W11-1(3). The images depict two-way trail traffic by different trail users to alert motorists to look in both directions before crossing the trail. A double-headed arrow can be added at the bottom of this sign to emphasize the two-way traffic to be expected on the shared use path.



Chapter 9: Grade Separated Crossings

Grade separated crossings include bicycle and pedestrian overpasses, bicycle and pedestrian underpasses. Bicycle and pedestrian overpass and underpass ramps should be designed to meet current ADA accessibility guidelines.

9.1 Overpasses

Overpasses or bridges are typically built to eliminate or avoid bicycle and pedestrian at-grade crossings of major highways or large roadways. Bridges are also used to enable shared use pathways across streams and rivers. Whether or not overpasses are a component of a shared use pathway or not, most pathway bridges in Loudoun County will need to serve both bicycle and pedestrian traffic. Bicycle/pedestrian bridges should provide a minimum of 10 feet of clear usable space on the ramps and span, or be equal to the width of the approaching pathway. If the bridge is a component of a major shared use path, it should have a minimum width of 12 feet. If the bridge is enclosed, the width should be expanded to 14 feet to reduce the tunnel effect. Roadway overpasses are most easily constructed and most effective when the street is partially or fully depressed and the bridge can be designed with minimal ramping.

9.2 Underpasses

Underpasses should be a minimum of 12 feet wide. Long narrow tunnels are uncomfortable for pedestrians. If the underpass is longer than 60 feet, the width should be 0.25 times the total tunnel length. Underpasses are most easily constructed and most effective when the road or railroad is elevated and the passageway is at or near ground level. The minimum vertical clearance for a bicycle/pedestrian underpass is 10 feet, 11-12 feet is preferred, particularly for underpasses longer than 60 feet.

A well-designed pedestrian tunnel has the following characteristics:

- Good lighting throughout.
- Allows natural light in when passing under the medians of large highways.
- Sufficient width and height to accommodate a variety of users and give a feeling of openness and safety.
- The exit is visible from the entry.
- Entrances are as visible as possible from adjacent streets and properties, so that users feel they are in view at all times.
- Serves clear origin and destination points and is well signed.
- Requires minimal (or no) out-of-direction travel.
- Crosses beneath a street with heavy traffic and fast speeds, where an at-grade crossing would be undesirable.
- Is visually and aesthetically appealing.



9.3 Lighting

Though adequate lighting is important to provide security on overpasses, it is a crucial factor in underpass design. Lighting of at least 108 lux (10 foot-candles) should be provided in tunnels and underpasses to improve security. In addition, variable level lighting (to match outdoor lighting closely) should be used in underpasses to accommodate persons whose eyes adapt slowly to lighting changes. White walls and roof openings can be used to increase lighting levels in tunnels.



Chapter 10: Designing Residential Communities for Bicycling and Walking

This chapter discusses critical design features and design criteria that should be used to guide land development, site design and street and public space design in residential developments. The elements of this chapter will most often be used to guide the planning and design of new residential developments. Many of the elements presented here are also applicable to community revitalization efforts and improvement projects for existing streets.

10.1 Design Principals

Following are a list of bicycle- and pedestrian-friendly design principals that should be used to guide both new residential development and revitalization of existing residential neighborhoods. These principals are also applicable to mixed-use developments that include residential components.

Proximity to Basic Land Uses: In mixed-use and residential developments, the siting of residential units in relationship to other uses such as retail shopping, public institutions and services, parks, and work places should maximize the number of people that live or work within reasonable walking or bicycling distances of these destinations (walking: 0.25-0.75 miles; bicycling: 0.5-2.5 miles). To the extent possible, schools, parks and shopping centers should be centrally located. In developments that are primarily residential in character, housing units should be sited to maximize the number of people that are within reasonable walking or bicycling distances of nearby retail shopping, public institutions and services, parks and work places. Strong consideration should be given to incorporation of some amount of retail, commercial or other non-residential land use within or along the edge every major residential development.

Directness and Continuity: Bikeways and walkways should be designed to provide direct, uninterrupted, and seamless connectivity between each residential neighborhood and between residential neighborhoods and other destinations both within and outside the development.

Accessibility: Public travel ways, public spaces and the bicycle and pedestrian network should ensure the mobility of all users by accommodating the needs of people regardless of age or ability.

Street Layout: While a variety of street layouts may be employed in residential developments. All patterns should be designed to provide a high degree of connectivity and directness for bicyclists and pedestrians. This may be achieved in a variety of ways: 1) by using a street pattern that inherently provides a high level of connectivity, 2) by using internal bicycle and pedestrian circulation systems to augment the street system, and/or 3) by augmenting a less connective street patterns with pass-through pathways, cul-de-sac connections, alleyways, public staircases, creek bridges, roadway underpasses, or other features that provide linkages for bicycles and pedestrians separate from motor vehicle access (see Figure 10.1.1). Even in a large residential development, the majority of units should have bicycle and pedestrian access routes to the surrounding collector or arterial roads of no longer than 0.3 miles.



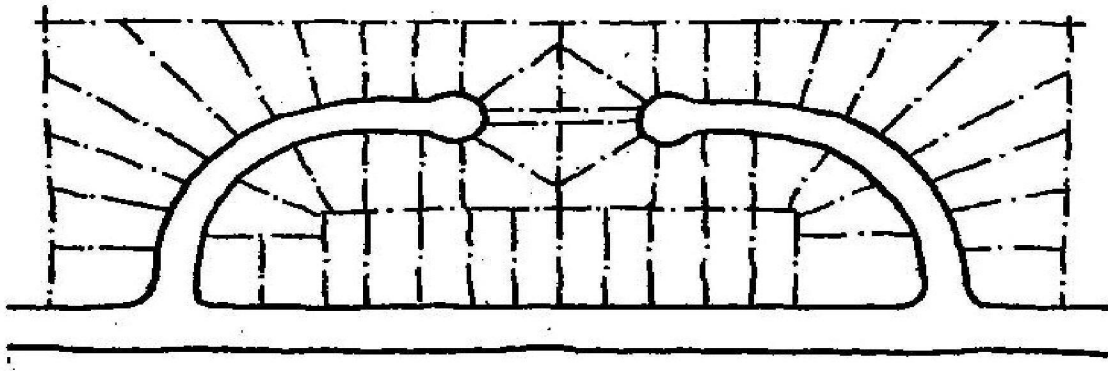


Figure 10.1.1 – Example of pathway connecting two cul-de-sac developments.

10.2 Street Design

There are six key features to bicycle and pedestrian-friendly street design for residential neighborhoods: street width, sidewalks, buffers, vehicle parking, using bike lanes where appropriate, and traffic calming.

Street width: Most residential streets should be narrow (21-34 feet) depending on their length, number of units served and housing type(s) served. Provision of on street parking is beneficial for bicycles and pedestrians as it reduces motor vehicle speeds and adds to the pedestrian buffer.

Sidewalks: Sidewalks should be provided on both sides of residential streets, with the exception of short dead-end streets or cul-de-sacs (less than 1000 feet in length). Severe topographic constraints, natural resources or adjacent land use characteristics can also make investment in a sidewalk on one side of a street unnecessary or prohibitively expensive. Residential sidewalks should be a minimum of 5 feet wide (per Plan Policy for Provision of Walkways and Sidewalks).

Buffers: Buffers should be 4-10 feet wide and vegetated. Street trees are highly desirable on residential streets for a variety of reasons including pedestrian comfort. In addition to buffering pedestrians from traffic and creating a space for shade trees to grow, buffers provide space for features that may be needed on higher density residential streets such as signs and utilities, street lighting poles, a bench or trash can, future bus stops and shelters, a place to put out trash for pick-up and added protection for children playing on sidewalks and in front yards. One of the most important benefits of buffers is that they provide space for driveway aprons to ramp up from the street without negatively impacting the cross slope of the sidewalk.

Motor vehicle parking: While on-street parking on one or both sides of residential streets improves conditions for pedestrians, if parking spaces are unoccupied or are used sporadically, the additional street width will be used by moving vehicles and higher speeds will be encouraged. This will significantly reduce the comfort of bicyclists and pedestrians using the street. Use of alleys and rear parking access parking is a good design approach for residential neighborhoods. See the next section, Connectivity in Community Design: Commercial, for multi-family residential parking lot design.

Bike Lanes: The typical traffic volumes and speeds on residential streets are so low that bike lanes are not necessary to achieve a high bicycle level of service. However, there are a number of situations where they may be considered or required to meet BLOS minimums, such as on collector streets in residential neighborhoods, on collectors or minor arterials in mixed-use developments, on streets that serve higher density residential development, or streets that have a strong urban design character. Bike lanes may also be appropriate on streets in residential neighborhoods if the street is a major access route to a school, major park, greenway trail or other high bicycle trip generator.

Traffic Calming: When patterned and designed properly, residential streets should not require traffic calming measures or retrofits. However, there are a variety of traffic calming measures that can be used in residential street design when they are first built. Two of these measures include the use of small roundabouts at key intersections and the provision of sharp bends or slow points at regular intervals. Depending on the residential density, role of the street in the neighborhood and type of neighborhood character that is desired, the following other features might also be considered: raised crosswalks, curb extensions, parking bays, chicanes, median barriers or forced turn channelization. Where medians breaks are not provided at street intersections, thus limiting vehicle turning movements at local access points, it is usually important to provide median breaks for bicyclists and crosswalks to the median for pedestrians.

10.3 Other Bicycle/Pedestrian-Friendly Design Features

There are a wide variety of other design features that facilitate bicycle and pedestrian connectivity in residential and mixed-use developments. Many of these features are also recommended for commercial developments as well. The specific design of these features will vary based on the specific characteristics of each site and the needs and concerns of the neighborhood served and adjacent property owners. The Portland Pedestrian Design Guide (developed by the City of Portland, Oregon) is a good source of detailed design guidance for public connector pathways and stairs.¹⁷ Additionally, the photos and graphics below provide illustrations of some of these features.

Following is a list of special features that can significantly enhance bicycle and pedestrian connectivity and improve the efficiency and attractiveness of bicycling and walking:

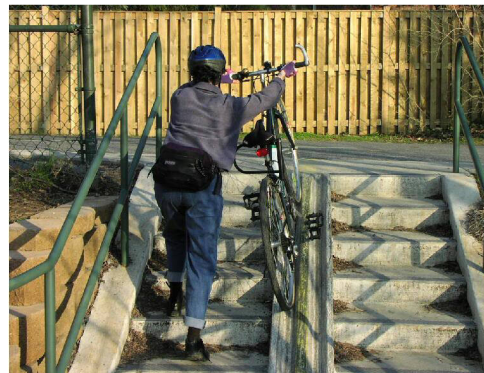
- ❑ **Internal Pathway Networks:** Internal pathway networks are most effective when residential areas are laid out with common green spaces and extensive linear park elements (see below for further details).
- ❑ **Short cuts and pass-through pathways:** Paved walkways between residential units are very useful for improving connectivity and directness for bicyclists and pedestrians in residential areas that are based on contemporary suburban or hybrid street patterns. These pathways should be used to



Example of a short cut path between a neighborhood and the W&OD Trail in Purcellville.

provide efficient links to the collector and arterial roads on the periphery of residential neighborhoods, provide linkages that shorten internal residential blocks, and provide access to greenway or other trails that are adjacent to the neighborhood. Linkages to major trails, such as the W&OD Trail, should be provided more, rather than less frequently, with full consideration of the trail's use for transportation purposes, as well as recreation.

- ❑ **Connected Cul-de-Sacs:** Many communities provide bicycle and pedestrian only connections between abutting cul-de-sacs, calling the resulting low traffic continuous routes.
- ❑ **Pathways across or around open spaces, bridges over streams:** Without pathways across or around open spaces such as meadows, ballfields, future building sites, retention ponds, forested areas, etc., large natural areas can become a barrier to efficient bicycle and pedestrian travel. Residential communities should also provide periodic bridges across internal streams and creeks that border developments. The location of stream crossings should be determined to maximize their use for utilitarian travel by providing efficient links to school sites, parks, shopping centers or residential collector roads.
- ❑ **Public Stairs:** In areas with significant slopes and grade changes, installation of public stairways can provide direct pedestrian access. Installation of narrow steel or concrete ramps can also make stairs passable for bicyclists.
- ❑ **Gates:** Gates in fences can improve bicycle and pedestrian access while providing some access control. In some locations gates can provide open public access during hours facilities are open and closures after dark or when supervisory personnel are not available on site. The use of passkeys can provide connections between private multi-family residential complexes and public trails or other bikeways and walkways.
- ❑ **Bicycle Parking:** Within residential communities, bicycle parking is important to provide at recreation centers, parks, schools, or other key destinations for the public.
- ❑ **Wayfinding Systems:** Special wayfinding signs highlighting key destinations are important for large residential neighborhoods, especially if they are designed with typical suburban street patterns. As more of the facilities described above are utilized in residential communities wayfinding system will be necessary to help local and non-local users find desired destinations and the most efficient routes.



Stairway bicycle ramp provides access to the Capital Crescent Trail in Bethesda, MD.

10.4 Internal Pathway Networks

Internal pathway networks should be developed in residential communities as a supplement to high quality bicycle and pedestrian accommodations within the street system. While there is a wide range of trail design issues that are relevant for internal trail systems, this Toolkit highlights those that are particularly key for Loudoun County.

Mid-block Crossings: Internal pathway networks often connect with neighborhood streets at mid-block locations where pathway traffic must merge or cross the street. Although these are typically low volume, low speed streets, special care needs to be taken in the design of mid-block crossings (for further details, see mid-block crossings in Chapter 7 of this Toolkit).

Pathway Widths: Internal pathways that are intended to serve both bicycles and pedestrians shall be at least eight feet wide. The higher use segments should be 10 feet wide. Widths less than eight feet will create safety problems on shared-use paths.¹⁸

10.5 Safety and Security

The following topics provide a few highlights of what should be considered regarding design for the safety and security of bikeways and walkways in residential neighborhoods and other locations:

Lighting: Pedestrian-scale lighting should be designed to light the walkway, therefore increasing pedestrian safety. Pedestrian lighting should be used in addition to lighting provided for motorists' safety. The Illuminating Engineering Society of North America (IESNA) provides guidance regarding the desirable lighting levels specified for pedestrian areas (see Table 10.5.1 below).¹⁹

Pedestrian Walkways	Commercial		Intermediate		Residential	
	Footcandle	Lux	Footcandle	Lux	Footcandle	Lux
Sidewalks	0.9	10	0.6	6	0.2	2
Pedestrian Walks*	2.0	22	1.0	11	0.5	5
Building Sites:			Values are given in minimum average maintained horizontal footcandles and lux.			
Entrances	5.0	55				
Grounds	1.0	11	* Crosswalks should be provided with additional illumination producing from 1.5 to 2 times the normal roadway lighting level.			
Parking Areas:						
Self Parking	1.0	11				
Attendant Parking	2.0	22				

Table 10.5.1: Recommended Pedestrian Illumination Guidelines

The unit of measurement above is the footcandle (1 unit of lux is equal to 10 footcandles). A footcandle is a unit of luminance on a surface that is everywhere 1 foot from a point source of 1 candle.



Vegetation: Vegetation creating green and natural landscapes is an important part of bikeways and walkways in every location, especially residential neighborhoods. The amount of greenery will vary considerably from what is provided on an arterial parkway, on a town center street, residential street or along a linear park trail. In residential communities, internal pathways should provide a balance between the need for vegetation and ensuring good sight lines for safe travel. Additionally, dense vegetation can contribute to personal security problems or the perception of a security risk.

Access Control: Keeping motorized vehicles off trails is often an issue. While gates can keep automobiles, trucks and off-road recreational vehicles off shared use paths, they can also create access difficulties for bicyclists, bikes towing trailers, wheelchair users and other intended trail users. Removable bollards are one method that can be used to restrict access to unauthorized vehicles and allow it for authorized vehicles. Bollards should never be used in pairs; rather one should be placed on each edge of the pathway and one in the middle. Bollards should include reflective material to make them visible at night and be spaced to allow pathway traffic safe passage at a low speed. Providing path users appropriate warning signs for approaching in-trail impediments is also necessary.

In some settings, large boulders and planter islands can also be used to provide effective and attractive access controls. In other settings, wood or metal railings can be configured (chicane) to effectively slow trail users at street crossings, allow them to pass through without stopping and restrict vehicular traffic as well.



Chapter 11: Designing Commercial and Institutional Development for Bicycling and Walking

This chapter discusses critical design features and design criteria that should be used to guide land development, site design and street design in commercial and institutional developments such as schools, colleges, libraries, post offices, government buildings, etc. The elements of this chapter will most often be used to guide the planning and design of new retail, office and other types of commercial/institutional development. However, many of the elements presented here are also applicable to redevelopment or revitalization efforts for commercial zones or along older commercial corridors. For greater detail regarding bicycle and pedestrian oriented design for commercial Main Streets see “Main Street...when a highway runs through it: A Handbook for Oregon Communities”²⁰ or other national Main Street resources.

11.1 Design Principals

The list of bicycle- and pedestrian-friendly design principals provided in the previous chapter can also be used to guide commercial/institutional development and revitalization. These principals are also applicable to mixed-use developments that include commercial components along with residential development. The following additional principals are particularly relevant to commercial/institutional developments:

Equal Access: In the design of commercial developments it is important to give the same level of attention and priority to points of access and access routes for bicyclists and pedestrians as is provided for auto and service vehicle access. Bicycle and pedestrian access can be integrated with automobile access, provided for separately, and/or sometimes integrated with service access.

Transit Access: When designing for pedestrian access it is important to also consider transit access. Most shoppers, employees or other visitors coming to a commercial development via transit will be arriving as a pedestrian, or making the transition from the transit trip to pedestrian mode at the edge of or on the commercial development. Building entrances should be oriented for ease of access by transit users.

11.2 Street Design

Most street design features that are important for application in commercial areas are already addressed elsewhere in this toolkit, including elements of what is described in the previous chapter, which addresses residential street design. In this section, a few additional tips are provided that apply to design issues unique to the context and needs of streets serving commercial and institutional uses.



Bike Lanes and Parking: The need for bike lanes on any particular street in a commercial development or area should be determined by applying the Bicycle Level of Service model, which will factor in existing and future traffic levels, traffic speeds, street width, etc. When bicycle lanes are placed adjacent to short-term on street parking that turns over regularly, bike lanes should be no less than 5 feet wide, 6 feet is preferred. It is important to provide bicyclists enough space to use the bike lane and avoid hitting a door opened by a driver getting out of a parked car. Marking the left edge of the parking bays and striping the right edge of the bike lane 1.0 to 1.5 feet to the right of the parking bay edge line can also make bike lanes safer in these situations.

Sidewalks and Buffers: Sidewalks should be a minimum of six feet wide on streets with commercial frontage. Sidewalks and buffers should be larger than the minimum in pedestrian high use areas and street furniture should also be provided in areas with retail shopping, restaurants and other commercial developments with high levels of pedestrian use.

Driveway Consolidation: Where streets provide access to off-street parking lots, uncontrolled access points (driveways) should be limited to those necessary for good access and circulation. Along a collector or arterial roadway, each additional driveway creates a conflict point for bicyclists and pedestrians.²¹

Traffic Calming: When patterned and designed properly, streets in commercial areas should not typically require traffic calming measures or retrofits. However, there are a variety of traffic calming measures that can be used on streets in commercial areas. Depending on the nature of the traffic in the area or specific development, role of the street and type of urban/suburban character that is desired, the following features might be considered: raised crosswalks, curb extensions, parking bays, median barriers or forced turn channelization. Where medians breaks are not provided at street intersections, thus limiting vehicle turning movements at local access points, it is usually important to provide median breaks for bicyclists and crosswalks to the median for pedestrians.

11.3 Site Design

The physical layout of a development can often make the difference in a person's choice to walk or bicycle. Careful attention should be given to the location of buildings as well as the configuration of parking lots. Several provisions can ensure a better walking and bicycling environment in commercial and institutional developments.

Building Setbacks and Orientation: When buildings are separated from the street by parking lots, pedestrian and bicycle access is discouraged. A setback of no more than 25 feet can encourage pedestrian activity. Parking, driving and maneuvering areas should be located on the side and rear in many commercial developments, or minimized in the front and redistributed to sides and/or rear areas. Main building entrances should be oriented with the facade facing the street. Additional entrances can be provided for side and rear parking areas. Entrances and paved walkways should be connected to the sidewalks along the street, transit stops (or likely future transit stop locations), as well as the parking lots. Visual stimulation is very important to pedestrians. Long, blank walls with no openings onto the street discourage walking. Areas between buildings and the street frontage should be landscaped. Building facades should



maintain continuity of design elements such as windows, entries, storefronts, rooflines, materials, pedestrian spaces and amenities, and landscaping.

Sidewalk Circulation Systems: Adequate sidewalk or pathway circulation systems should be included in all commercial developments and areas. These systems should be configured to connect various building entrances with the surrounding streets and parking lots. Generally, all on-site origins and destinations should be connected efficiently and attractively to encourage on-site pedestrian circulation. Where possible, vegetated landscape areas should be located between access walkways and building walls.

Special Bicycle/Pedestrian Features: There are a wide variety of special design features that facilitate bicycle and pedestrian connectivity in commercial and mixed-use developments (see chapter 9, section 9.3 for details). The specific design of these features will vary based on the unique characteristics of each site and the needs and concerns of the development and surrounding neighborhood and adjacent property owners. Internal pathway networks can be very useful in large office parks or campus type developments. Short cut paths are useful for making direct connections to adjacent land uses. Public stairs can improve the directness of pedestrian access when elevations must be traversed.

Bicycle Parking: Adequate, attractive and functional bicycle parking is a key ingredient for commercial and institutional developments. Bike parking is needed for employees, visitors, and customers. Short-term bike parking in the form of bicycle racks is usually adequate for visitors and customers. Employees often need parking accommodations that provide greater security and weather protection over a longer period of time. This can be provided with bike lockers, indoor bicycle storage rooms or fenced in bicycle parking areas in schoolyards or parking garages.

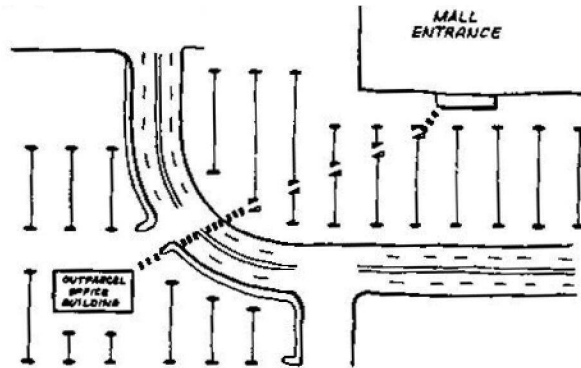
The most important consideration for short-term bike parking is to provide racks that support both the frame and wheels and allow locking of the front wheel and frame to the rack. Other considerations are providing sufficient quantity to meet demand, locating racks near entrances and in areas where they are not hidden from view, and providing parked bicycle protection from the weather. The most common error made in the procurement of bicycle parking racks for schools and business is choosing a rack (such as the “Toast” or “Comb” racks) that supports only one wheel of the bike (not the frame) and is difficult to lock-up to with a standard U-lock. The Association of Pedestrian and Bicycle Professionals provides an excellent set of bicycle parking guidelines²².

Parking Lots and Garages: Parking lots with fifty spaces of more should be divided into separate areas with combined walkways and landscaped areas that provide access to building entrances. In general, parking lots should provide direct pedestrian paths from parking lots and parking decks to the buildings that they serve. These paths can be delineated with striping, different paving materials, or by situating the path through the center of a series of strategically placed parking islands (see Figure 11.3.1). Combined landscape and walkway strips that separate linear parking rows should be at least 10 feet wide.



Some retail shopping establishments and other commercial uses can generate large numbers of both pedestrian and auto trips. Additionally, some have frequent customer turn over rates. Parking lots serving these types of businesses should be oriented away from the building entrance that will generate the most bicycle and pedestrian access trips. Building complexes that mix uses such as office and retail can be oriented with pedestrian plazas or zones between selected entrances. In office complexes and shopping centers, out parcel uses as a retail store, bank, cleaners or restaurant should be connected by a pedestrian walkway (see Figure 11.3.1).

Figure 11.3.1: Pedestrian walkways and crosswalks across parking lots provide pedestrian access and connectivity.



Parking lot layout that enables pedestrian access to outparcel developments (from TRB Research Report 294A)

Parking garages with street frontage should be designed with ground level retail fronting the sidewalks to increase pedestrian activity levels and security. Street frontage should also be designed with space for existing or future transit stops in mind.

Crosswalks in Parking Lots:

Crosswalks should be provided within most parking lots unless very low volumes of pedestrian and vehicular traffic are expected. They should be a part of direct pedestrian paths that lead from parking lots to the buildings that they serve. Crosswalks can be delineated with striping, different paving materials, or by aligning them through the center of a series of strategically placed parking islands. Where added safety is desired or higher pedestrian volumes need to be served, raised, speed-table crosswalks can be used to slow cars and mark the best pedestrian crossing locations.

Pick-up/Drop-off Areas: Strip retail shopping plazas, grocery stores, hotels and other institutions often provide drop-off and loading zones along the front or side of the building between the building and parking areas. While these areas are very useful for building access and egress, they must be designed with pedestrian and traffic safety in mind. They should include 5-mph speed limits, curb ramps and crosswalks to the parking isles and periodic speed humps or speed table crosswalks. The setback and design of support columns that may be used to support covered areas over the building entrance area (or the store front itself), should ensure that pedestrians waiting for pick up, or to cross the entrance lane, can easily be seen by motorists using the lane.

Internal Streets: Large commercial developments with large parking lots can be best organized for all modes of travel by creating internal street systems. These street systems should be clearly laid out and marked (with curbs or striping), and facilitate vehicular flow using the same traffic operational patterns as the public street system. Landscaping islands can be used to separate travel lanes from parking bays and travel lanes from pedestrian walkways. Lane striping and signing will help users comply with desired flow patterns, and can regulate space sharing between motorists, service vehicles, pedestrians and bicyclists.

Site Plan Checklist: Following is a site plan checklist that will ensure high quality bicycle and pedestrian access in commercial developments:

- Does the plan meet ADA standards?
- Are all buildings, separate commercial spaces and “out buildings” connected by walkways and bicycle accessible travel ways?
- Are drop-off and pick-up areas designed for easy use and pedestrian safety? Can they be crossed safely; are waiting pedestrians visible and protected from through traffic? Are traffic calming measures used to ensure compliance with low speed limits?
- Are utilitarian access paths provided? Do they provide direct and effective bicycle and pedestrian connections to activity areas nearby, to nearby residential neighborhoods? Can pedestrians and bicyclists take advantage of shortcut, rear and side access paths that encourage walking instead of driving?
- Does the bicycle and pedestrian circulation system consider the type and probable location of future development on adjacent or nearby parcels of land? Is there flexibility to provide direct connections to adjacent parcels, should that be desired in the future?
- Are building entrances convenient, accessible and safe for pedestrians and bicyclists? Are they designed and located to provide safety relative to nearby motor vehicle traffic? Are they made clearly evident by design features, topography, signing or marking?
- Is sufficient bicycle parking provided for customers/visitors? Is it located close to the entrance? Can it be found from the primary bicycle access routes to the site? Is it convenient and easy to use, protected from the weather?
- Is sufficient bicycle parking provided for employees? Is it located close to the employee entrance? Can it be found from the primary bicycle access routes to the site? Is it secure, easy to use, and protected from the weather? Is it located properly relative to showering and changing facilities?
- Are landscaping and lighting used to enhance the pedestrian experience and add safety and security, especially at night?
- Are pathways generally visible from nearby buildings and free from dark, narrow passageways?
- Are crossings of wide expanses of parking lot held to a minimum?
- Are sight lines at intersections adequate for pedestrian/bicyclist visibility? Are pedestrians and bicyclists able to see on-coming traffic, given typical speeds?
- Do pathways lead to road crossing points with the least conflict?
- In general, are pedestrian/vehicle and bicycle/vehicle conflict points kept to a minimum?
- At signalized intersections within the development or adjacent to it, do signal phases give pedestrians adequate time to cross the road?



Chapter 12: bicycle and Pedestrian Design in Towns and Villages

This chapter will provide a brief summary of the types of bicycle and pedestrian accommodations that should be considered for Loudoun's rural towns and villages. The elements of this chapter will most often be used to guide the planning and design of retrofit projects in Loudoun's existing small towns and villages. However, these concepts are also applicable to new residential developments in rural Loudoun that are based on the village concept and street pattern.

12.1 Design Principals

A very different set of design principals are needed to guide community, roadway, bikeway and walkway design in rural towns and villages. Issues in these communities typically include 1) how to deal with high speed, high volume roads that pass through the village center, 2) how to increase safety for children, the elderly, bicyclists and pedestrians, and 3) how to improve bicycle and pedestrian travel accommodations within constrained rights-of-way, while preserving rural and historic character, valuable natural resources, and minimizing costs. The following design principals can be the basis of effective solutions under these conditions:

Balance: There is a need to balance the competing needs of through traffic and local traffic, and balance the needs of all road users, including motorists, bicyclists, pedestrians, residents and adjacent property owners. However, safety in traffic should be a preeminent concern, especially for the most vulnerable road and street users. Pedestrian and bicycle safety should not be sacrificed for the sake of faster through traffic.

Flexibility: Because of spatial and other constraints, flexibility should guide facility design. Crossings and facility dimensions will need to be customized to each particular situation. Planners, designers, residents and facility users need to be willing to think “outside the box” and try new designs, facility types, operational dynamics and traffic control devices. Loudoun’s rural towns and villages have very constrained rights-of-way therefore creative approaches are necessary.

Public Involvement: Because the effected public is smaller and more clearly defined in rural towns and villages, retaining meaningful public involvement throughout the design process will increase opportunities to achieve consensus, meet most needs, and maximize community acceptance of the improvements that emerge.

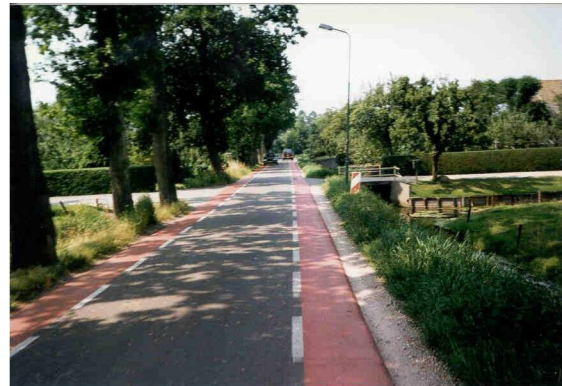
12.2 Design Features

Basic Sidewalks and Shoulders: In most cases, providing basic sidewalks, five feet in width, should be the first objective of most village improvements. For a variety of reasons, sidewalks may not be the most desirable or feasible accommodation, in which case, striped and paved shoulders may be an option to consider. A roadway shoulder that doubles as both a pedestrian walkway (because there is no adjacent sidewalk) and a signed bikeway should be six feet wide.²³ In a village or rural setting, shoulders between 3-6 feet can provide both bicyclists and



pedestrians improved accommodations that can be shared, however the facility should not be designated as a formal bikeway, and appropriate SHARE THE ROAD SIGNS should be used.

Hybrid Shared Roadways: A hybrid, shared roadway is a unique treatment that is more commonly used in Europe. It may be an appropriate design for select rural roads, village streets or lanes in Loudoun County. Locations where this facility may be most useful should have the following conditions: 1) the existing roadway cross sections are narrow, 2) road widening to provide increased paved shoulder width is not feasible for historic preservation, environmental or other reasons, 3) traffic speeds need to be kept to levels that are compatible with motorist, bicyclist and pedestrian safety, and 4) traffic volumes or other conditions impacting bicycle and pedestrian use suggest that non-motorized accommodations and/or safety improvements are needed. This treatment can be applied to a rural road, street or lane of between 18 and 26 feet wide. The design provides combined bicycle/pedestrian lanes, 4-6 feet wide, on the outside edges of the roadway using white striping and a distinctive red pavement (see photo).



Hybrid shared roadway, European example.

A roadway centerline stripe is not provided, and there is no grade differential or curb provided to delineate the designated bicycle/pedestrian travel lanes on the edges from the basic roadway pavement in the middle. The overall width of the road does not allow two motor vehicles to pass without using the bicycle/pedestrian lanes. Thus, motorists are required to share the combined bike/pedestrian lanes with non-motorized road users. Speed limits on such roads should be established at 15-25 mph; and signs would instruct motorists to yield to bicyclists and pedestrians using the combined bike/pedestrian lanes and pass on the left when there is no oncoming traffic. Special signage would be required for all road entry points and along the road as well.

Gateway Treatments: Gateway treatments at the edges of rural towns and villages can be useful roadway improvements because they can address a multitude of needs. They can be used in combination with other roadway features to help calm traffic on main thoroughfares that traverse the centers of towns and villages. They help road users to know that the context of the road is changing and they have arrived at a place with a name, where people live, work and go to school. They can also be an element of village pride that is designed and cared for by village residents and communicates to the outside world something about the character of the place and its inhabitants. Gateway treatments can include roadside landscaping, small structures, place name and welcome signs and other compatible features. They can be combined with speed limit zones, lane narrowing, median islands, dynamic striping in the travel lanes that signal the need to slow down, and other features that offer direct traffic calming influences.

Wonerf: The wonerf is a Dutch idea that takes traffic calming to its ultimate realization. The term wonerf means “living street.” A wonerf is a residential street that has been designated primarily for foot traffic, bicycles and children playing – automobiles are treated as guests. The street is designed with physical constraints that allow only local motor vehicle access (residents and visitors) at low speeds (under 10 mph). Signs are posted warning entering motorists of the special street characteristics; the signs depict pedestrians, children playing, houses and automobiles. The road space must be shared and motorists must yield to all other uses. The wonerf concept may be applicable to certain streets in existing villages and small towns, as well as some streets in new developments that using the village model. The wonerf may also be applicable on select streets in larger residential developments in suburban Loudoun or the larger towns such as Leesburg and Purcellville.



European Wonerf

Traffic Calming: Certain traditional traffic calming treatments are also applicable to Loudoun’s small towns and villages. Techniques that are appropriate for the main thoroughfares in villages will be different from those that can be used on side streets and lanes. Applicable treatments include raised crosswalks, small roundabouts, landscape center islands, speed humps, curb extensions, chicanes, median islands, forced turn channelization, entry restrictions, one-way chokers, and others.

Chapter 13: Bikeway Signs

13.1 Designating Bike Routes

Signing of shared roadways indicates to cyclists that there are particular advantages to using these routes compared to alternate routes between the same places. This means that the responsible agencies have taken action to ensure that these routes are suitable as shared routes and will be maintained as such.

In Loudoun County, there are several reasons for designating signed bike routes:

- a) The route provides connectivity to other bicycle facilities such as bike lanes and shared use paths.
- b) The route extends along a series of minor streets that
 - would be difficult to follow without signs,
 - provide a relatively direct through route between major destinations, or
 - lead to an internal neighborhood destination such as a park, school, trail access point or commercial district, that would be hard to find otherwise.
- c) The route is the preferred route among more than one potential route between major destinations; it may include specific improvements made to enhance bicycle safety and convenience, or may have conditions more favorable to bicycling.
- d) In rural areas, the route is preferred for bicycling due to low motor vehicle traffic volumes, high scenic and destination values and/or the presence of a paved shoulder.

Routes that meet any of these criteria should be evaluated to determine if the conditions along the route are adequate for bicycling. If the route is determined to be suitable, bike route signs can be installed along the route.

For bike route signs to be effective, they must regularly and clearly indicate which direction to go to remain on the route. Signs should be installed at each turn along the route and periodic signs should be placed along long straight sections of the route to provide a sense of comfort to cyclists that they have not accidentally strayed from the designated route. Destination information must be included. Major and minor cross streets should be signed (with the route and destination information) when they cross the designated route, to indicate that bicyclists can join the route at this location. Consideration should be given to providing distance information to destinations or as a route placement reference.



The green route designation signs in the MUTCD are suitable for urban and suburban routes that are used primarily for transportation. An aesthetically distinctive sign can be considered for rural routes that are designated primarily for recreational bicycle touring. The use of route numbers or names to differentiate routes from one another is optional. Bicycle facility maps and automobile traveler guides (ADC Maps) should be updated to include route designation information.

13.2 Share the Road Signs

SHARE THE ROAD signs are designed to be used in situations where there is a need to warn drivers to watch for slower forms of transportation traveling along the roadway, such as bicyclists and pedestrians. It is also warns bicyclists and pedestrians that they will be required to share vehicle travel lanes along this route.

SHARE THE ROAD signs should only be used on roads that have poor conditions for bicyclists (no shoulder or narrow lanes) or pedestrians (no shoulder or sidewalk) but are still frequently used. Clarke's Gap Road is a good example of a road that should be signed with this treatment. *SHARE THE ROAD* signs are not for designating bike routes nor should they be placed on roadways with good bicycling and pedestrian conditions. The image at right depicts a *SHARE THE ROAD* sign for bicyclists. This bicycle sign (W11-1) could be replaced with a pedestrian sign (W11-2) or a combination sign as shown in Section 8.3.



Endnotes

- ¹ *Guide for the Development of Bicycle Facilities*, American Association of State Highways and Transportation Officials (AASHTO), 1999, p. 3.
- ² *Guide for the Development of Bicycle Facilities*, American Association of State Highways and Transportation Officials (AASHTO), 1999, p. 2.
- ³ *Guide for the Development of Bicycle Facilities*, American Association of State Highways and Transportation Officials (AASHTO), 1999, p. 3.
- ⁴ *ibid.*, p. 6.
- ⁵ *Tech Sheet #1- Sidepath Bicycle Facilities*, Randy Neufeld and Terri Musser, Chicagoland Bicycle Federation, 1997.
- ⁶ *Guide for the Development of Bicycle Facilities*, American Association of State Highways and Transportation Officials (AASHTO), 1999, p. 36.
- ⁷ *Manual on Uniform Traffic Control Devices (MUTCD)*, FHWA, 2000, p. 4L-1.
- ⁸ See Section 4L of the MUTCD for a more complete discussion of this device.
- ⁹ *Traffic Control Devices Handbook*, Institute of Traffic Engineers, 2002.
- ¹⁰ *ADAAG for Buildings and Facilities, as amended through September 2002*, U.S. Access Board, section 4.29 Detectable Warnings.
- ¹¹ *Draft Guidelines for Accessible Public Rights-of-Way*, U.S. Access Board, June 17, 2002, section 4.29 Detectable Warnings.
- ¹² Conventional driveway entrances are connected to the street via a concrete apron.
- ¹³ *Safety Effects of Marked vs. Unmarked Crosswalks at Uncontrolled Locations: Executive Summary and Recommended Guidelines*, FHWA, 2002, pp. 17-28.
- ¹⁴ *Traffic Control Devices Handbook*, Institute of Traffic Engineers, 2002.
- ¹⁵ *Traffic Controls for Bicycle Facilities – Part 9*, Federal Highway Administration, MUTCD Errata No. 1, June 14, 2001
- ¹⁶ *Innovative Bicycle Treatments – An Informational Report*, Jumana Nabti and Matthew Ridgway, Institute of Transportation Engineers, May 2002
- ¹⁷ *Portland Pedestrian Design Guide*, City of Portland, Office of Transportation, 1988, p. D-5.
- ¹⁸ As with public sidewalks, which are typically 4-8 feet wide, child bicyclists can be allowed to use pathways of less than eight feet, however use for general cycling is not recommended.
- ¹⁹ *IESNA Roadway Lighting report (ANSI/IESNA RP-8-00)*.
- ²⁰ *Main Street...when a highway runs through it: A Handbook for Oregon Communities*, Oregon Department of Transportation and Oregon Department of Land Conservation and Development, 1999.
- ²¹ *Oregon Bicycle and Pedestrian Plan*, Oregon Dept. of Transportation, 1995, p. 43.
- ²² *Bicycle Parking Guidelines*, Association of Pedestrian and Bicycle Professionals, 2002; www.apbp.org
- ²³ *ibid.*, p. 95.

